ASPECTS OF FEEDING THE HILL EWE

DURING PREGNANCY

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Ph.D.

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1985

I hereby declare that I have composed this thesis myself, and, except where otherwise stated, the work contained herein is my own.

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February 1985

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ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr J.A. Milne for his continual help and encouragement throughout the experimentation and preparation of this thesis, and to Drs A.J.F. Russel and A.W. Illius for their encouragement and advice. I would also like to thank the present and former Directors of the Hill Farming Research Organisation, Mr J. Eadie and Professor J.M.M. Cunningham, for providing me with facilities at H.F.R.O.

The technical assistance and advice on computing provided by Mrs A.M. Spence and Mrs H.A. McCormack was very much appreciated, as were the shepherding skills and considerable practical help given by Mr H. Habblett and Mr J. Turner. I gratefully acknowledge the contributions of: Mr E. Skedd, Miss P.E. Moberly and Mr J. McKenzie in carrying out many of the plasma, ruminal and faecal analyses; Mr D.R. Campbell for the *in vitro* digestibility determinations; Miss H.K. Smith and Mr E.A. Hunter for statistical advice; Mr I.R. Pitketh͡ly for advice and considerable assistance with the vegetation mapping of Birnie hill and for advice on the preparation of figures used in the manuscript; Dr R.W. Mayes for advice on the use of Ru-Phen and for assisting in the preparation of the Ru-Phen cellulose powder used in Experiment 4; Mr A Sibbald for writing the computer programme to facilitate the positioning of fence lines on Birnie hill and for the data on lamb losses in Fig. 4.3, and Mr W. Souter, Miss K Richardson, Dr J. Eddison and Mr A.J. Senior for occasional assistance with sampling procedures.

Thanks are also due to Mrs E.B.H. Reid, Mrs J.P. Mabon and Mrs M. Purves for typing various draft copies, and to Mrs R. Mascall for typing the final manuscript. I wish to thank Mr F. Thompson of Rumenco Ltd. for his interest, and for the provision of feedblocks used in these experiments.

Finally, I acknowledge the provision of a three year Postgraduate Scholarship from the Agricultural Research Council.

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LIST OF ABBREVIATIONS

A/F	Agrostis/Festuca
BL	Border Leicester
CP	crude protein
Cr	chromium
CRL	crown rump length
Cr_2O_3	chromium sesquioxide
CS	condition score
CV	coefficient of variation
D	date of birth
DM	dry matter
DMI	dry matter intake
DOMI	digestible organic matter intake
DV	dominance value
EC	ethyl concentrate
EDTA	ethylene diamine tetraacetic acid
HFRO	Hill Farming Research Organisation
H_2SO_4	sulphuric acid
ME	metabolisable energy
N	nitrogen
NEFA	non esterified fatty acids
NH_3	ammonia
3-OHB	3-hydroxybutyrate
OM	organic matter
OMD	organic matter digestibility
OMI	organic matter intake
r_s	Spearman's correlation coefficient
RMS	residual mean square
Ru-Phen	ruthenium phenanthroline complex
SB	Scottish Blackface
SE	standard error
SD	standard deviation
VFA	volatile fatty acids
VI	voluntary intake
W	Kendall's coefficient of concordance

ABSTRACT

Responses in ewe and lamb performance to mid pregnancy supplementation and to the method of providing the supplement were examined when Scottish Blackface ewes grazed heather dominant hills in winter.

In these experiments, ewes grazed areas with 20% Agrostis/Festuca and 80% heather at a stocking rate of 2 ewes/ha during mid pregnancy, and were adequately fed in late pregnancy. Treatments were compared where ewes were unsupplemented in mid pregnancy or where a barley based supplement supplying 1.6 - 1.8 MJ ME and 3 - 6 g N/d, mainly as urea, was offered. Mid pregnancy supplementation reduced ewe liveweight and condition score losses, and there was a linear relationship between these two factors and lamb birthweight, which was increased with mid pregnancy supplementation by 10% over three experiments.

When areas with 20 - 40% Agrostis/Festuca vegetation were grazed at stocking rates of 1.2 - 2.1 ewes/ha to create a four fold difference in herbage allowance of Agrostis/Festuca, there was no effect on ewe liveweight change during mid pregnancy, and a response in lamb birthweight was obtained only in 2-year-old ewes. These findings were supported by the small differences found in the concentrations of plasma urea and ruminal ammonia, and in the in vitro digestibility of oesophageal extrusa samples collected from sheep grazing areas of Agrostis/Festuca during the mid pregnancy period. In a further experiment, diet selection differences attributable to herbage mass at the start of the winter were not manifest where Agrostis/Festuca swards had a herbage mass of less than 3,000 kg DM/ha (with approximately 10% green material) and where ewes were grazed at 2/ha. It was inferred that the benefits of mid pregnancy supplementation could apply to a wide range of heather dominant hills.

No gross differences in ewe and lamb performance were found with the use of hand fed pellets, compared with self help feedblocks in mid pregnancy. Voluntary intake of feedblock was related to the composition of the supplement, but was not affected by the siting of feedblocks either on heather or on Agrostis/Festuca areas, by

hardness or by the use of containers. Considerable variation in daily group intakes of feedblock occurred when voluntary intakes of feedblock were high, and the frequency of replenishment was restricted, but the variation was also high when feedblocks were offered ad libitum. Variability between ewes in feedblock intake was high. There was a significant rank correlation in feedblock intakes by ewes in a group, which suggested that, with an understanding of the factors affecting intake, this variability could be reduced.

Social dominance explained 25% of the variation in supplement intake when feedblock was offered ad libitum. Two-year-old ewes were of lower social rank, had lower supplement intakes, and were the most numerous non-feeders. A simple device to identify non-feeders was successfully tested. It was considered that the high coefficients of variation between days and between animals in intake of feedblock might lead to inefficient use of the nutrients supplied.

CHAPTER 1: INTRODUCTION

There are approximately 1.2 million ha of heather dominant land in the U.K. (Thomas, 1956), and it has been estimated that 30% of the sheep population in Scotland is found in heather dominant areas (Grant and Milne, 1972). In traditional 'set stocked' systems of management, less than 25% of the annual herbage DM production is utilized, compared with 70% for lowland situations (Eadie, 1970), and it was against this background that the two pasture system, the concept of which has been discussed recently by Eadie (1978), was developed. A practical guide to the system was published by ADAS (1975). Basically, the ewes are grazed on better quality pasture, which has been improved by grazing management or reseeding, at key points of the production cycle i.e. in the premating/mating and lactation periods. It was thought that poor mid winter nutrition of the sheep was not inconsistent with good performance provided that nutrition in late pregnancy was kept at adequate levels by the use of purchased supplements and that the ewes had adequate body reserves at the start of mid pregnancy (Russel, 1971).

However, further development of the Systems, as described by Eadie, Armstrong, Maxwell and Currie (1976), had led to the situation where mid winter nutrition may limit ewe performance on predominantly heather hills. The removal of what are often the better areas of hill pasture for pasture improvement, coupled with increases in the stocking rate, will intensify grazing pressure on the remaining grassy areas particularly in winter, and lead to a greater proportion of herbage of lower nutritive value such as heather being consumed.

Indoor studies on the provision of supplements with heather (Milne, Christie and Russel, 1979) and heather: Agrostis/Festuca (A/F) diets (Milne and Spence, unpublished; Mayes and Lamb, 1982) indicated the nature and amounts of supplement which would reduce nutrient deficits but not depress the intake of the basal diet. However, these supplements had not been tested under field conditions.

Until 1979, evidence from the literature concerning the importance of nutrition in mid pregnancy on the growth of the products of conception was conflicting. Since then there has been an increasing body of evidence to suggest that the importance of

nutrition in mid pregnancy has been underestimated in the past (Mellor, 1983).

The principal objective of the work reported in this thesis was to examine the need for mid pregnancy supplementation in the context of improved systems of management on heather dominant hills.

Another issue worthy of consideration is the method of supplementation in extensive hill situations. The use of feedblocks has become increasingly popular. Stern (1973) reported increases in sales (from estimates within the manufacturing industry) from 1,000 tons in 1963 to 15,000 tons in 1970, and 40,000 tons in 1973. At the time of the article there were more than 30 different feedblocks on the market. Lloyd (1977) reported from a survey of 413 flocks in Wales that 37% of hill flocks received supplement in the form of feedblocks, and this rose to 48% where flock size was greater than 100 ewes, reflecting the labour saving attributes of self help supplements where ewes ranged over extensive areas of land. To date, little objective research has been undertaken to quantify the nutritional effects of this method of supplementation on the performance of ewes on extensive hill grazings, and this formed the second area of study of the Thesis.

CHAPTER 2: REVIEW OF THE LITERATURE

Development of the ovine conceptus (Section 2.1)

The development of the ovine conceptus has been described in recent reviews by Robinson (1982) and Mellor (1983). Only the main points of interest will be outlined here. The pattern of growth of the foetal tissues, placenta and fluids of the conceptus are illustrated in Figure 2.1.

Placental development begins around 30 days after conception and the number of placentomes associated with each foetus is fixed at this stage, the number decreasing with increasing litter size (Alexander, 1964; Rhind, Robinson and McDonald, 1980). Growth of the placentomes continues until approximately 90 days (Alexander, 1964; Stegeman, 1974; Robinson, McDonald, Fraser and Crofts, 1977), and during this period compensatory hypertrophy may occur in multiple pregnancies, reducing the initial imbalance in placental development (Mellor, Mitchell and Matheson, 1977; Rhind et al, 1980).

Foetal growth has been described in ewes slaughtered at different stages of pregnancy (Wallace, 1948, Joubert, 1956; Langlands and Sutherland, 1968; Rattray, Garrett, East and Hinman, 1973 and 1974). More recently, Robinson et al (1977) applied the Gompertz equation to foetal growth: this describes the exponential fall in specific foetal growth rate as pregnancy advances. The use of such an equation is interesting, since it implies that differences in lamb birthweight associated with litter size originate before the last 4 - 5 weeks of pregnancy (Robinson et al, 1977) when absolute foetal growth rates are at their highest.

A new technique involving the implantation of a device into the foetus at 60 - 70 days (Mellor and Matheson, 1979; Mellor and Murray, 1982) has enabled foetal growth rate (expressed in terms of increments of foetal crown-rump length (CRL) and foetal girth over time)to be continuously monitored in the living animal. In well nourished ewes, foetal growth rate remains constant until around 120 days of gestation, and thereafter gradually declines in relation to placental weight (Mellor and Matheson, 1979; Mellor and Murray, 1981 and 1982b).

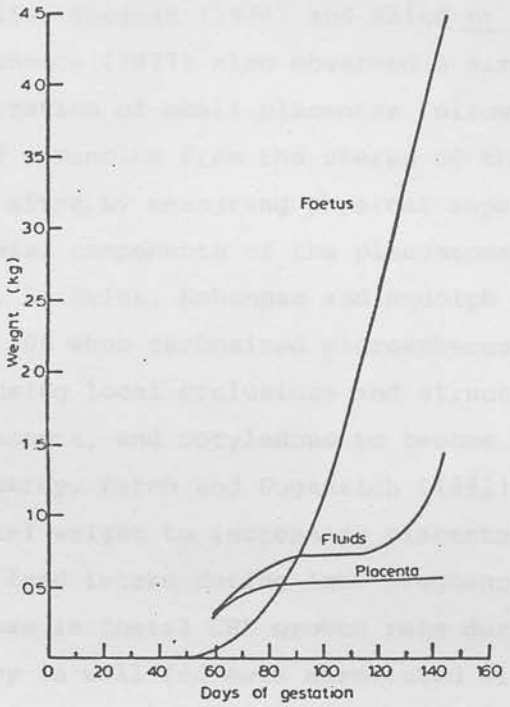


Figure 2.1 The growth of twin foetuses and their associated placenta and fluids for a ewe, liveweight 70 kg at mating (from Robinson, 1982).

The positive relationship between placental weight and lamb birthweight has been discussed fully by Mellor (1983). Previous observations on the same effect were made in man by McKeown and Record (1953), and since then in sheep by Alexander (1964), Kloosterman (1965), Stegman (1974) and Rhind et al (1980). Mellor Mitchell and Matheson (1977) also observed a similar effect by inducing the formation of small placentae following the removal of large numbers of caruncles from the uterus of the ewe before conception, and after, by measuring physical separation of the maternal and foetal components of the placentomes at 80 days. Creasy, Barrett, De Swiet, Kahanpaa and Rudolph (1972) reduced lamb birthweights by 30% when carbonized microspheres were induced into the arteries causing local occlusions and structural alterations in parts of the placenta, and cotyledons to become fibrous.

Davis, Rattray, Petch and Duganzich (1981) found that the response of foetal weight to increasing placental mass increased with increasing feed intake during late pregnancy.

The decrease in foetal CRL growth rate during the last 20 - 30 days of pregnancy in well fed ewes associated with a placental limit on nutrient supply, and in particular glucose, has been discussed by Mellor (1983). Foetuses with low weight placentae carried by well nourished ewes display chronic and progressive hypoxaemia and chronic hypoglycaemia in late pregnancy.

Thus, although placental weight may be only a crude index of transfer function, since compensation may occur as a result of increased branching and vascularization of villi (Stegman, 1974), by increases in maternal and foetal blood flow (Makowski, Meschia, Droegemueller and Battaglia, 1968 ; Mellor, 1983) in late pregnancy and a possible increase in transfer of nutrients via the intercoty ledonary area, it seems likely that, even in the well nourished ewe, foetal growth rate is ultimately limited by placental size, which is itself determined by around 90 days of gestation.

Studies on the effects of undernutrition on the growth of the conceptus in mid pregnancy (Section 2.2)

Studies of the effects of maternal nutrition before 90 days have produced variable results. Foetal weights may vary widely in different ewes within the same litter (McDonald, Robinson and Fraser,

1981) which renders the serial slaughter technique rather insensitive, especially when the small size of the foetus prior to 90 days, by which time it has only reached some 15% (Robinson, 1977) of its birthweight, is considered. Thus, while Wallace (1948) found no effect of undernutrition on foetal weight which was sufficient to cause a drop of 7% maternal liveweight before 90 days, Everitt (1964, 1966) observed a 7 - 11% reduction in foetal weight when Merino ewes were underfed to reduce their liveweight by 12 - 15% of that of controls over a similar period.

Everitt (1964) reported that cotyledon weights of a low treatment were 69% those of the high treatment, and in a study by Clark and Speedy (1980) where foetal weights were reduced by a low plane of mid pregnancy nutrition to 98% of those of the high plane, cotyledon weights were reduced to 90% of the weights found on the high plane treatment. These results suggest that the placenta may be more sensitive to undernutrition in mid pregnancy than the foetus.

However, Parr, Cumming and Clark (1982) and Parr and Williams (1982) observed a reduction in foetal size as early as day 21 with undernourished ewes. Their treatments were very severe; ewes were offered a maintenance energy level, or 25% of maintenance energy level as rations. Since placental development does not start until around day 30, it is likely that these effects were mediated by hormones and their effects on uterine fluids (Ménézo and Wintenberger-Torres, 1976).

Specific growth rates are at their highest in early pregnancy, with daily increases in weight of 20% (Robinson et al, 1977). Brasel and Winick (1972) argued that malnutrition in the hyperplastic phase of growth may interfere with cell division, leading to irreversible deficits in cell number and permanent effects on growth. The effects are greatest in those tissues dividing most rapidly at the time of the stimulus. Thus it may be that severe reductions in the level of maternal nutrition can have a direct effect on the foetus very early in pregnancy, when its absolute nutrient requirements are very small. With less drastic treatments El-Sheikh, Hulet, Pope and Casida (1955) and Foote, Pope, Chapman and Casida (1959) found no effect of nutrition on embryo size in

early pregnancy, and indeed most of the studies of the effects of nutrition at this stage have been concerned with embryo loss (see review by Edey, 1976). Studies on foetal loss brought about by undernutrition in mid pregnancy (Hodge, 1966; Coop and Clark, 1969; Curll, Davidson and Freer, 1975) have not demonstrated any reduction in lambing percentage.

Most of the studies on the effects of nutrition in pregnancy use lamb birthweight as the main criterion, which is reasonable in view of the relationships between lamb birthweight and mortality (Purser and Young, 1959) and subsequent lamb growth rates (Everitt, 1967; Alexander, 1974; Russel, Doney and Eadie, 1978). However, levels of nutrition at different stages of pregnancy may intereact e.g. a high plane of nutrition in mid pregnancy might spare tissue reserves for late pregnancy, as well as having a direct effect on the conceptus. Taplin and Everitt (1964) and Everitt (1966, 1967) suggested that at least partial compensation for poor mid pregnancy nutrition could occur with liberal feeding in late pregnancy, although McClymont and Lambourne (1958) had already shown that this was unlikely if return to a high plane of nutrition was left until after the 16th week of pregnancy. In discussing compensatory growth Mellor (1983) considered any effects of a high plane of nutrition in late pregnancy to result from a slowing down in the reduction in growth rate which occurs at this time, rather than an actual increase in growth rate. Thus it is unlikely that complete compensation will occur. The situation is further complicated by the findings of Rattray, Trigg and Urlich (1980), to the effect that a very thin ewe may utilize abundant food in late pregnancy to restore body condition rather than for foetal growth. Initial ewe liveweight (Davis et al, 1981) and body condition at mating (Clark and Speedy, 1980) may also influence placental development and lamb birthweight.

Many of the studies have been carried out with grazing sheep and the severity of the treatments indicated in terms of liveweight loss. As Russel, Gunn and Doney (1968) and Field, Suttle and Gunn (1968) have indicated, liveweight change is the result of increases in uterine contents, and changes in gut fill as well as tissue loss, and is, therefore, not necessarily a good descriptor of the plane of

nutrition. Notwithstanding such difficulties of interpretation, Table 2.1 summarises some of the experiments described in the literature relevant to the mid pregnancy period.

The evidence is somewhat conflicting, but it would seem that liveweight losses greater than 10% of liveweight at mating are likely to lead to a reduction in lamb birthweight, particularly when undernourishment continues through late pregnancy to lambing, and that the effects might be greatest in young ewes and older ewes bearing twins. There is therefore a need to quantify the effects of supplementary feeding within the context of systems of hill sheep management, since the mechanisms whereby responses can be predicted have not yet been elucidated.

Evidence has been put forward for direct effects of nutrition on foetal and placental growth, though there is little evidence in the literature to suggest whether the supply of protein or energy substrates to the tissues is limiting. Curet (1973) found a reduction in foetal weight at 90 days when ewes were offered a protein-deficient diet, but the number of ewes studied was very small. Critical experiments need to be conducted to list whether the supply of protein or energy substrates limits placental or foetal growth in mid pregnancy, or whether reducing mobilization of maternal tissues in mid pregnancy conserves this source of energy for use in late pregnancy when the demands of the foetus for glucose and amino acids are high. It may well allow these nutrients to be spared for foetal growth.

From the evidence presented here, it is likely that mid pregnancy nutrition affects the growth of the placenta which reaches its maximum size by 90 days. This then limits the growth of the foetus in late pregnancy by restricting the supply of nutrients. Further evidence for this comes from the work of Mellor and Murray (1982a). They fed Scottish Blackface ewes 0.6 - 0.8 of recommended ME intakes (according to ARC, 1980) throughout pregnancy, producing a loss in liveweight of 5 - 10% of mating weight. Foetal growth was measured using crown rump length and foetal girth as described by Mellor and Matheson (1979) and Mellor and Murray (1982b). Placental weights at 142 days were some 15% lighter in the

Table 2.1 The effects of nutrition in mid pregnancy on lamb birthweight

Reference	Breed and age of ewe	Duration of treatment	Weight change as % mating weight where applicable	Plane of nutrition in in late pregnancy	Consequences for lamb birthweight
McClymont and Lambourne (1958)	-	Mating to 16 weeks	Controls 20% heavier than treatment ewes at week 16	Half ewes offered 'high', half 'low' plane of nutrition	A mean reduction in birthweight of 6% No evidence of compensation due to late pregnancy feeding.
Bennett, Axelson and Chapman (1964)	2-year-old Merinos and Border Leicester (BL) x Merino ewes	0 - 6 weeks 8 - 14 weeks	Controls gained 5% Treatment lost 24%	All animals grazed adequate pasture	30% reduction in birthweight of single lambs born to 2-year-old Merino ewes. 4% reduction in singles and 8% in twin lambs born to 5-year-old BL x Merino ewes
Hodge (1966)	3-year-old BL x Merino	Mating to 13/15 weeks	Controls gained 2 - 7% Treatments lost 15 - 17%	All animals grazed adequate pasture	No effect on birthweights of single or twin lambs.
Monteath (1971)	2½-year-old Romney ewes	6 - 16 weeks	Controls maintained liveweight, treatment lost 15%.	High quality pasture until lambing	No effect on birthweights.
Russel and Foot (1973)	2-year-old Scottish Blackface (SB)	0 - 14 weeks	Controls gained 1.5 kg Treatment lost 4.5 kg	Half of each treatment fed either 'high' or 'low'.	Non significant decrease of 5% in birthweights of singles. No evidence of compensation at levels of late pregnancy nutrition offered.
Curll, Davidson and Freer (1975)	3-year-old BL x Merino ewes	Mating to 15 weeks 3 levels of liveweight at mating.	Range from loss of 16% to gain of 24% over mid pregnancy.	All animals grazed high quality pasture until lambing.	Regression analysis showed that liveweight gaine over the first 15 weeks accounted for 94% of the variation in lamb birthweight.
Russel, Foot, White and Davies (1981)	2-year-old SB ewes initial liveweight) flock A 42.4 kg flock B 54.5 kg initial condition score) flock A 2.4 flock B 2.9	4 - 14 weeks	Controls gained 6% Treatment lost 6%	Offered supplementary feed to supply from 0.44 to 0.73 MJ ME/ $kg^{0.75}$ from weeks 14-21	Flock A birthweights of single lambs reduced by 9% by mid pregnancy treatment: Flock B birthweights of single lambs increased by 17% by mid pregnancy treatments.

undernourished ewes when compared to those from a well fed control group, and were related to foetal CLR, growth and weight. Foetal growth rates in undernourished ewes decreased progressively from between 90 - 111 days. Since refeeding such ewes from 120 days of gestation did not increase foetal growth rate, Mellor (1983) argued that feeding large amounts of supplement to hill ewes in late pregnancy is unlikely to do anything more than limit the progressive fall in foetal growth rate. It is concluded that, in determining the pattern of supplementation for pregnant hill sheep, a case has been made for greater importance to be given to the mid pregnancy period than is currently recommended or practised.

The nutrition obtained from heather (Calluna vulgaris) and Agrostis Festuca (A/F) diets in winter by sheep (Section 2.3)

Milne (1974) has described the nutritive value of frozen harvested heather. The material harvested was subsequently shown to be similar to that ingested by grazing sheep (Milne, Grant and Bagley, 1979). Organic matter digestibility (OMD) declined from 0.46 in November to 0.43 in March. Apparent digestibility of N was very low, and the animals were in considerable negative N balance. The low apparent digestibility of N and the lack of relationship between the N content of heather and voluntary intakes was attributed to the presence of tannins in the heather inducing the formation of protein-tannin complexes. From a comparison of heather with other low quality roughages, low voluntary intakes were considered to be major factors limiting the nutritive value of heather. Subsequent work by Christie (1978) showed that palatability of heather was unlikely to be an important reason for the low voluntary intakes, but supplementation with small amounts of N increased the voluntary intake of heather by 60% (Milne, Christie and Russel, 1979). Increasing the amount of N above 0.5 g/day gave no further response in voluntary intake, and concentrations of plasma urea and ruminal NH_3 suggested that energy supply to the rumen had become the limiting factor to further increases in voluntary intake. When energy was added in the form of 105 g starch/day, intakes of heather were not depressed, and the total intakes of DOM from the whole diet were considered adequate for the maintenance of a housed animal.

Though heather may form an increasingly important component of the diet in winter, it is unlikely to provide the only source of nourishment for hill ewes grazing a predominantly heather hill. Herbage from areas of A/F pasture is of potentially very high quality (Eadie, 1967) though the fund of dead material (of low digestibility (Eadie and Black, 1968)) reduces the ability of the animal to select a high quality diet in winter. Christie (1978), compared the chemical composition, OMD and voluntary intake data for heather (Milne, 1974) and winter harvested A/F (Lamb and Eadie, unpublished data), and found that although OMD values were similar, apparent N digestibility values were some 20% higher and voluntary intakes of the A/F diet were almost twice that of heather. More recently, MacRae, Milne, Wilson and Spence (1979), have described the N digestion of these forages and found lower amounts of non-ammonia N absorbed with the heather diet, reflecting the low availability of N in the rumen, and in the small intestine with the heather diet. When the voluntary intakes of frozen, harvested A/F: heather (1/3rd: 2/3rds) mixtures were compared in indoor experiments with intakes predicted from values for the two components offered separately (Milne and Spence, unpublished data) the actual intakes were higher than predicted values, suggesting that A/F was acting as a supplement to heather. Data from this experiment and a further experiment (Milne, Spence and McCormack, unpublished) comparing the voluntary intakes and digestibility of the basal diet when a supplement was offered or not are listed in Table 2.2.

Table 2.2 Voluntary intakes of organic matter (OMI), organic matter digestibility (OMD) and digestible organic matter (DOMI) of diets of heather or A/F offered ad libitum and when 1/3rd A/F : 2/3rds calluna offered ad libitum with or without a supplement of 105 g starch, 3 g N/sheep/day (means of 5 observations).

		OMI ($g/kgw^{0.75}$/day)	OMD	DOMI of herbage ($g/kgw^{0.75}$/day)
Heather		24.1	0.42	10.2
A/F		37.2	0.475	20.6
Ave SE		2.77	0.0087	1.85
2/3 heather:1/3 A/F	Predicted	28.4	0.442	13.7
	Actual	35.1	0.457	16.3
2/3 heather: 1/3 A/F + 105 g starch, 3 g N/day		39.6	0.434	17.0
Ave SE		2.08	0.0069	0.96

These data illustrate the importance of the proportion of A/F in the diet, although there was no evidence of substitution of roughage intake by a supplement supplying 1.5 MJ ME (as starch) and 3 g N (as urea) per day up to inclusions of 1/3 A/F in the diet. Subsequent work by Mayes and Lamb (1982) showed that with a diet of 2/3 heather and 1/3 A/F, the supplement increased volatile fatty acid production rate and the amount of non ammonia N absorbed from the small intestine by 39%.

From indoor studies, it therefore appears that a low cost supplement based on barley and urea could supply a daily intake which would not depress roughage intake. It is difficult to estimate the amounts of ME supplied by grazed vegetation to determine the suitability of such a supplement for feeding over the mid pregnancy period to use on a heather dominant hill. Grazing sheep may have requirements 50% higher than those of housed sheep (Langlands and Bennett, 1973) although intakes by the grazing animal may also be higher (for example, if voluntary intakes from the indoor studies of Milne (1974) are compared with those of Milne, Bagley and Grant (1979)). This, coupled with the findings that some use of body reserves in mid pregnancy is not inconsistent with good ewe and lamb performance (Russel, 1971), illustrates the need to examine the use of such a supplement under field conditions if the response to mid pregnancy supplementation by ewes grazing a range of hill pastures is to be adequately quantified.

The method of feeding the supplement (Section 2.4)

Self help supplements may be provided either as solids or as liquids dispensed in drum-roller or float-lick dispensers (Mutch, 1966; Alexander, 1971). The liquid supplements are mainly molasses/urea mixtures designed to supply a source of nitrogen and energy to stimulate microbial digestion of poor quality roughage in the rumen. The solid blocks range from purely mineral/salt supplements to blocks of low intake potential where the nutrients act as a supplement to poor quality roughage, and to blocks of high intake potential for periods of high nutrient requirement and where substitution of forage intake is acceptable.

The basic methods of feedblock manufacture have been described by Kendall (1977) and include the use of compression and binding agents, such as bentonite, lignin sulphonate, molasses and distillery by-products, e.g. ethyl concentrate (E C) feed. This is used in the 'Rumevite' range manufactured by Rumenco Ltd, Burton on Trent and which occupied some 70% of the feedblock market in 1973 (Stern, 1973). Similar binding agents have also been used in the preparation of 'feedblocks' on farm (Tulloh, Watson and Burnell, 1963). The chemical setting process involves the reaction of calcium oxide or hydroxide with molasses forming calcium sucrosate. A fourth method involves the use of steam and pressure in the extrusion of the material through a die.

The composition and physical nature of the feedblock are likely to affect intakes, but there is little published information on this topic. The use of salt to regulate intake was developed for supplements ingested by animals grazing arid pastures. Weir and Miller (1953) used 25% salt in a salt/cottonseed meal supplement offered to pregnant ewes fed dry rations indoors, to limit supplement intakes to 115 g/ewe/day, but the supplement intake more than doubled over the 16 weeks of the experiment. Beames (1963) limited intakes of a salt/urea/molasses lick offered to cattle to approximately 100 g/hd/day for 24 weeks, but the level of inclusion of salt was 47.5%. Furthermore, Bishop and Grobler (1971) found that 60% salt inclusion was necessary to limit intakes by weaner cattle, on spared sourveld, of a fishmeal lick to 0.65 kg/hd/day. It is likely that salt content would have little value in control of supplement intake in U.K. conditions.

Other constituents of feedblocks may affect palatability. Pearce and Raven (1973) found that increasing the urea content of feedblocks offered to Friesian steers reduced intakes. Bishop and Grobler (1971) recorded lower intakes where urea constituted 15% of a block compared with another containing fishmeal, but with 60% salt compared with 30% for the former. However, palatability responses may by different in different species, since Goatcher and Church (1970a) observed different responses in cattle, sheep and goats to molasses and sodium chloride. Other factors which

may affect feedblock intake are hardness, availability of other feedstuffs, the number of feedblocks available and the use of containers (Kendall, 1977). The siting of the supplement and the rate of replenishment of feedblock could also be important, but these factors have not been studied. Climate may also influence intakes by changing the surface of the feedblock, or by making it more obvious to grazing stock (e.g. with snow cover (Ducker and Fraser, 1975). There is no information on the relative importance of each of these factors and how they are likely to interact with one another. There is thus a need to describe the factors affecting supplement intake within systems of hill sheep management.

Most studies have described the performance of animals in relation to the nutrients supplied by self help supplements rather than by describing the use of such supplements per se (e.g. Beames, 1965; Boling, Bradley and Lovell, 1971). Those studies where individual intakes of feedblocks were measured indicated wide variation between animals and, where comparisons were made with handfed supplements in troughs, higher variation in intakes with feedblocks (Kendall, Ducker and Hemingway, 1980; Kendall, Hemingway and Ducker, 1980; Lobato and Pearce, 1978). Since variation in intake is affected by trough space (Kendall, Hemingway and Ducker, 1980), care must be taken when making comparisons, and coefficients of variation are only strictly comparable when mean intakes are similar. In many studies trough space is not given or comparisons not made at equal intakes. Wide variation in intakes of liquid supplements have also been observed (Nolan, Ball, Murray, Norton and Leng, 1974; Nolan, Norton, Murray, Ball, Roseby, Rohan-Jones, Hill and Leng, 1975; Mulholland and Coombe, 1979). It is likely that the factors affecting supplement intake described above may also affect variation in supplement intake between animals. Other factors such as age of ewe (Foot, Russel, Maxwell and Morris, 1973), teeth status (Kendall, 1977) size of ewe, social behaviour (Lobato and Pearce, 1978; Lobato and Beilharz, 1979) and nutritional demands of individuals within a group have also been implicated. However, neither Kendall (1977) offering feedblocks, or Foot et al (1973) offering pelleted feedstuffs in troughs, could find any evidence of this latter factor.

Prior to 1979, there was no information on the pattern of intakes of self help supplements under extensive hill conditions. Ducker, Kendall and Hemingway (1981) published results of a survey undertaken on several hill farms describing the variability in intake of feedblocks between sheep. Coefficients of variation ranged from 46 - 231%, but no information was available about many of the factors which may influence feedblock intake.

There is thus a need to quantify the pattern of intakes of self help supplements under extensive conditions and to try to identify the factors affecting the wide variability in intakes which have been observed. Feedblocks have been developed for potential use over the entire period of pregnancy, whereas liquid supplements are considered to be of most benefit in improving the intake of low quality roughage supplements. For this reason, and because of their greater useage, a study of the use of feedblocks is likely to be of more value.

CHAPTER 3: EXPERIMENTAL SECTION

EXPERIMENT 1: the effects of supplementation in mid pregnancy and the proportion of A/F on a heather-dominant hill on ewe and lamb performance

INTRODUCTION (Section 3.1.1)

It has been argued in Section 2 that the level of nutrition obtained by hill ewes in mid pregnancy from heather-dominant hills with improved systems of sheep management may have a detrimental effect on subsequent ewe and lamb performance even when the ewes are adequately nourished in late pregnancy. However, the magnitude of improvement in ewe and lamb performance to be expected from supplementation in mid pregnancy has not been quantified. Since there is evidence that the intakes of N and ME from A/F pastures in winter are likely to be considerably higher than when heather forms a major portion of the diet (see Section 2), the proportion of A/F on a heather-dominant hill should be significant.

Both these means whereby mid pregnancy nutrition could influence ewe and lamb performance were studied. A comparison was made between 2 treatments in which ewes were unsupplemented in mid pregnancy; one where A/F covered 0.20 of the area and one where A/F covered 0.40 of the area, the remainder being predominantly heather. A further comparison was made between a treatment in which ewes were unsupplemented during mid pregnancy and grazed an area with 0.20 A/F and 2 treatments where ewes grazed areas with similar proportions of A/F but received supplement in mid pregnancy.

Work by Milne, Christie and Russel (1979), Mayes and Lamb (1982) and Milne and Spence (unpublished data) had suggested the type and amount of supplement that should be fed. The methods of feeding such a supplement under field conditions had not been investigated. The supplement could be provided as hand fed pellets offered once daily in troughs or as self-help feedblocks. Evidence discussed in Section 2 pointed to difficulties in controlling supplement intake and to the high variability between sheep in supplement intake with feedblocks (e.g. Ducker et al, 1981), although no critical experimentation comparing feedblock and pellet usage in extensive hill situations had been conducted. A comparision was made on the supplemented treatments in mid pregnancy between a

hand fed supplement and a self-help feedblock, offered to supply the same intakes of N and ME, to quantify the pattern and variability in intake by ewes.

MATERIALS AND METHODS (Section 3.1.2)

General description of experimental area

The experiment was undertaken on the Birnie hirsel at the Hill Farming Research Organisation's Glensaugh Research Station, Kincardineshire, Scotland. The hirsel comprises both sides of a U-shaped valley running approximately North to South, forming 152 ha of heather-dominant rough grazings within a perimeter fence. Adjoining improved pasture associated with the hirsel totals 35.5 ha.

The area lies to the north of the Highland Boundary fault, which runs through the Research Station, and soils of the Strichan Association, developed from schistose rock, predominate. Brown ~~Earth~~ soils of the Fingarth series occupy the lower slopes, giving way to podsols and peaty podsols of the Gaerlie series on the higher slopes.

The western facing slope was enclosed by running a fence along the valley bottom, to provide an area of 98 ha reasonably consistent in aspect (facing East), topography and distribution of the vegetation. The hill rises steeply (gradient approximately 1:3) from 150 to 200 and 250 m at south and north ends respectively. Above this, the southern end comprises a series of irregular hillocks, reaching an altitude of 250 - 260 m. At the northern end the hill rises unbroken to 330 m (gradient approximately 1:8). Plate 1 shows the area viewed from the south east.

Vegetation

The vegetation of the area was surveyed in October/November, 1979. Four major plant communities were recognised:

1. Agrostis-Festuca (A/F) grassland. Principal species included Agrostis tenuis, Festuca ovina and Festuca rubra.
2. Heather (Calluna vulgaris, L. Hull). Heather dominant: further classified according to age, as pioneer, building or mature stand (Gimingham, 1972, pp 125 - 127)
3. Flush. Rushes, mainly Juncus effusus and Juncus acutifloris, dominating a mixture of grasses and sedges.

Plate 1 Birnie hill winter grazing area viewed from the South East

4. Mosaic. Agrostis-Festuca spp. and Calluna vulgaris finely integrated with neither dominant.

Large areas of A/F grassland, and to a lesser extent the heather and mosaic communities, were dominated by bracken, Pteridium aquilinum. The presence or absence of bracken was recorded within each plant community. The cover of A/F spp under bracken was variable and the method used to describe this community more fully is given below.

Vegetation Mapping

A map showing the perimeter fence line and location of streams was produced from OS sheet NO67NE, 1:10,000 enlarged to 1:20,000. The steep lower slope of the hill, as described above, was mapped by photography. Marker posts were positioned on the hill at the corners of adjacent quadrilaterals, with sides of 90 m. The posts allowed the formation of two rows of quadrilaterals and a third and lower row was produced from corner posts and natural features which could be identified and located on the map. In this latter row, quadrilaterals were of different size and shape. All corner markers were located by compass bearings to position the quadrilaterals accurately on the map. Fig. 3.1 shows a diagram of the area with quadrilaterals drawn in place. Photographs were taken from the west facing side of Birnie hill using a 12.7 x 10.2 cm base-board camera (Linhof Technika, West Germany), aligned opposite to the quadrilateral being photographed on the other hill face. The film used was Ektachrome 64 printed onto Cibachrome paper. The vegetation types were identified by colour and pattern, and a typical photograph is shown in Plate 2.

The quadrilaterals were divided into units equivalent to 30 m^2, but because of distortion owing to perspective and camera angle, those on the photographs were a different shape to those drawn on the map. To ensure that an area on the photograph was quantitatively transcribed to the map, the quadrilaterals were divided as follows: diagonals were drawn dividing a quadrilateral into four, and it was then divided again by lines from the apex of the triangles formed by the extension of the opposite sides. This process, illustrated in Fig. 3.2, was repeated until each

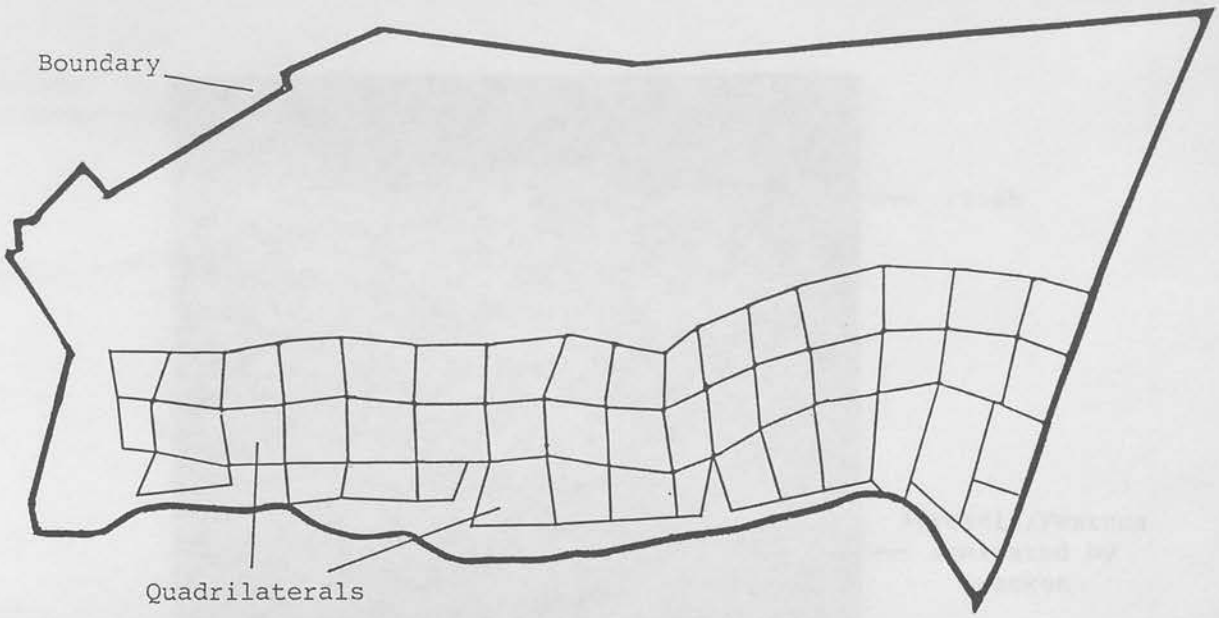


Figure 3.1 Outline of Birnie hill with quadrilaterals drawn in place.

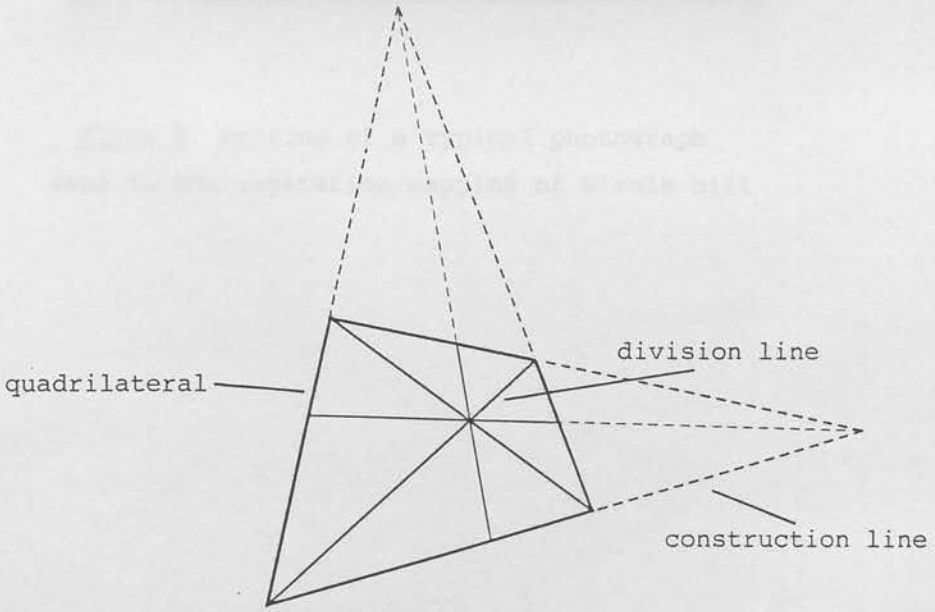


Figure 3.2 Process of bisecting quadrilaterals

Plate 2 Portion of a typical photograph used in the vegetation mapping of Birnie hill

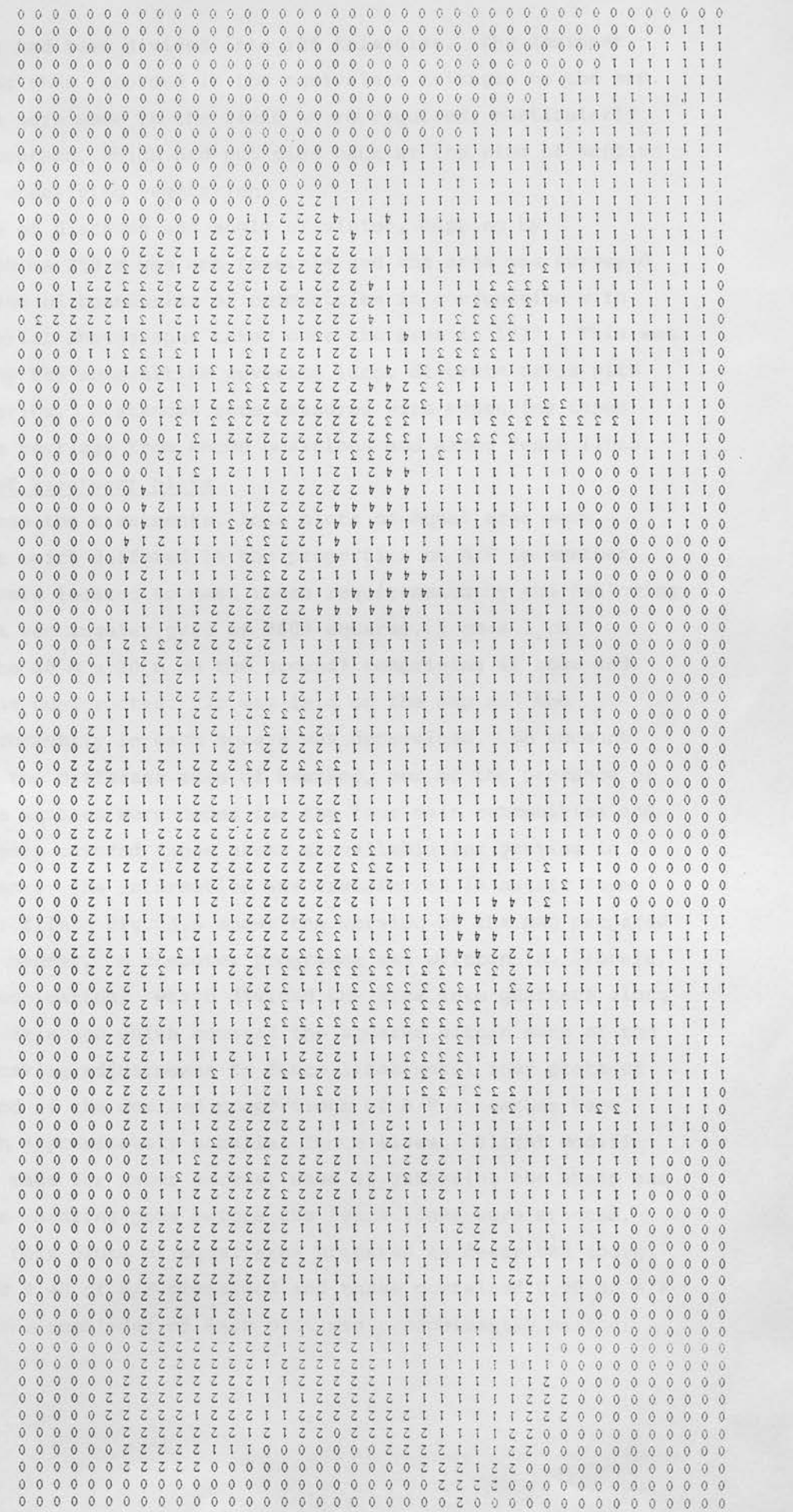


Figure 3.3 Vegetation map of Birnie hill in matrix form.

quadrilateral had been divided into 128 triangles. The dominant vegetation was then recorded in the equivalent triangle on the map. Verifications were made in the field where required, particularly where dense bracken, which had not died back at the time of mapping, obscured the underlying vegetation.

Because of distance and angle of vision, mapping by photography above 250 m was not feasible and the area was surveyed by the location of boundaries of communities in conjunction with the use of aerial photographs taken over the area in 1977. This was facilitated by the communities covering large discrete areas with smooth boundaries. Distances were measured with measuring tapes along compass bearings from known positions and along fence lines.

Preparation of treatment plots

To impose the treatments, four plots of equal area were required, but which differed in the proportion ot A/F to heather. Fence lines were located to meet these requirements by the following procedure. A rectangular grid of 3608 squares, 1 cm x 1 cm (equivalent to 20 m x 20 m on the ground) comprising 41 rows and 88 columns was constructed. It was laid on the map and the predominant community in each square was determined. No account was taken of the different ages of heather, nor of the presence of bracken. The squares were coded for the four main communities and a fifth category covered those areas unavailable for grazing in this experiment. The information was transferred in matrix form to a computer file. Fig. 3.3 shows the version of the map prepared in the above manner. A computer programme was written (A. Sibbald, personal communication) which divided the area into quarters along its vertical axis and which counted the squares within each of the four areas, making adjustments to fence lines until four plots of equal area and of the desired proportions of A/F : heather were obtained with approximately parallel fence lines. Slight modifications were made for water access, ease of gathering the sheep and siting of the handling pens before the fence lines were erected.

Of the four plots of equal area prepared as described above, one contained 0.40 of A/F grassland and three contained 0.20 of A/F grassland; the remainder of each plot was predominantly heather

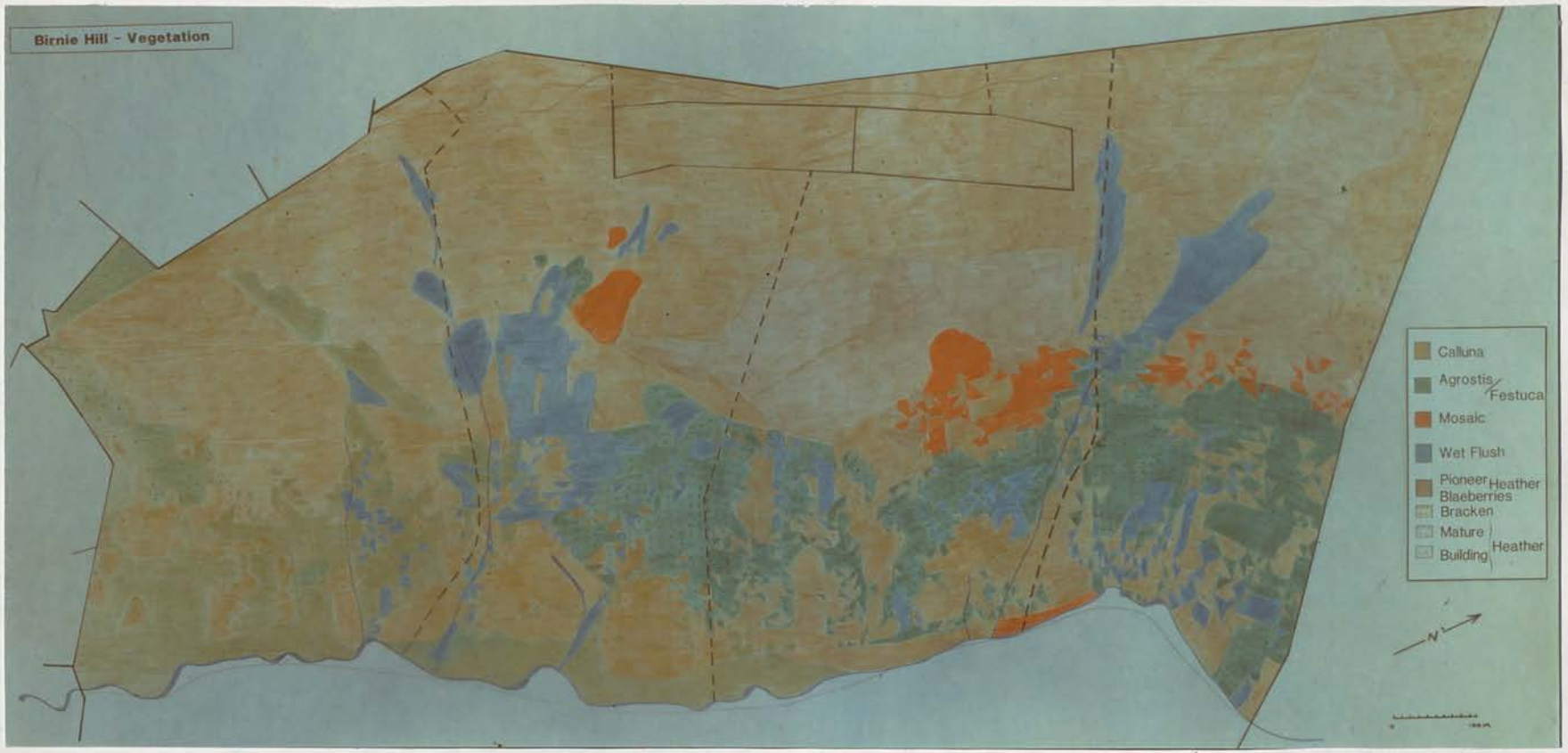


Plate 3 Vegetation map of Birnie hill with plot boundaries

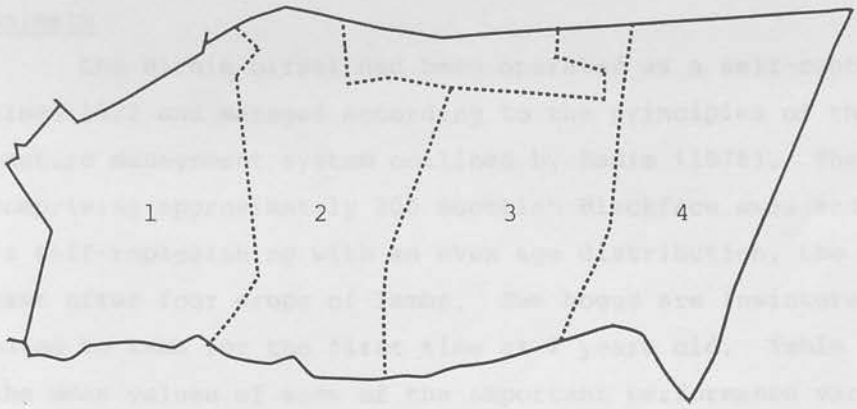


Figure 3.4 Plan of plots on Birnie hill

together with small areas of flush vegetation. The completed map with plot boundaries is shown in Plate 3.

Treatments

The following four treatments were imposed on 198 Scottish Blackface ewes from 4 January to 11 April, 1980:

A No supplementary feeding in mid pregnancy, ewes grazing area with 0.4 A/F grassland.

B No supplementary feeding in mid pregnancy, ewes grazing area with 0.2 A/F grassland.

C Supplementary feeding by feedblock in mid pregnancy, ewes grazing area with 0.2 A/F grassland.

D Supplementary feeding by pellet in mid pregnancy, ewes grazing area with 0.2 A/F grassland.

Ewes on treatment A grazed plot 1 and the other treatments were randomly allocated to the remaining plots (see Fig. 3.4). The mid pregnancy feeding period was from 4 January to 7 March 1980, (median days 35 to 98 of pregnancy). The amounts of supplement allocated to treatments C and D in mid pregnancy provided a mean daily intake of 1.5 MJ Metabolisable Energy (ME) and 3 g Nitrogen (N) per ewe. All ewes were given supplementary feeding in late pregnancy and were undernourished to the same extent as predicted from the concentrations of 3-OH Butyrate (3-OHB) in plasma. The stocking rate was approximately 2 ewes/ha on each plot.

Animals

The Birnie hirsel had been operated as a self-contained unit since 1972 and managed according to the principles of the two-pasture management system outlined by Eadie (1978). The flock, comprising approximately 200 Scottish Blackface ewes and gimmers, is self-replenishing with an even age distribution, the ewes being cast after four crops of lambs. Ewe hoggs are inwintered and mated to lamb for the first time at 2 years old. Table 3.1 shows the mean values of some of the important performance variables for 1978 and 1979.

Table 3.1 Mean performance of ewes on Birnie hirsel in 1978 and 1979

Ewe liveweight at mating (kg)	55.0
Proportion of ewes barren	0.11
Lambing rate (live lambs/ewes mated)	1.18
Birthweight of single lambs (kg)	4.35
Birthweight of twin lambs (kg)	3.45
Weaning rate (live lambs/ewes mated)	1.07
Liveweight at weaning of single lambs (kg)	27.9
Liveweight at weaning of twin lambs (kg)	25.1

In October 1979 there were 198 ewes and gimmers. Their age distribution is shown in Table 3.2.

Table 3.2 Age distribution of ewes at October 1979

Age (years)	No. of animals
2	57
3	52
4	49
5	30
6	10

From mid-August until mid-October, 1979, all ewes grazed on the hill area. Thereafter they grazed the improved pasture associated with the hirsel and were joined with rams fitted with marker crayons on 22 November 1979. Marked ewes were recorded weekly and the number of ewes mated in each week is given in Table 3.3.

Table 3.3 The number of ewes mated in each week after the introduction of rams

Age of ewe (years)	Week 1	2	3
2	25 (8)*	19 (0)	10 (0)
3	28 (3)	21 (0)	3 (0)
4	36 (9)	10 (0)	3 (0)
5	20 (2)	8 (0)	2 (0)
6	5 (0)	5 (0)	0 (0)

* Figures in brackets are returns to service.

No ewes were marked after week 4. The ewes remained on the improved pasture with the rams until 4 January 1980 when they were allocated to 4 groups balanced for age, mating date and liveweight. The groups were randomly allocated to treatments. There were 50 ewes on Treatments A and B and 49 ewes on Treatments C and D (198 ewes in all).

Feeds

Mid pregnancy It was intended that the feedblock used in Treatment C and the pelleted supplement used in treatment D should have the same ingredients but it proved impossible to produce pellets of the feedblock mixture that were not extremely hard and unpalatable. Thus, the two supplements differed slightly in ingredients, but barley formed the cereal base in both cases, and similar amounts of N were added as urea. The feedblocks were made by Rumenco Ltd., Burton on Trent, U.K. to meet the experimental specification. The composition of feeds together with their chemical analysis is given in Table 3.4. Chromium sesquioxide (Cr_2O_3) was incorporated into both feeds at a rate of 2 g/kg DM feedblock and 3 g/kg DM pellet.

To meet the daily intakes of N and ME, 140 g DM of pelleted supplement and 155 g DM of feedblock were offered per ewe. The pellets were cylindrical, 1 cm in diameter and 1 - 3 cm in length and were offered between 1000 and 1200 h daily at the lowest point of the plot. The ewes given the pelleted supplement were group-fed. A trough space of 0.5 m/ewe along one side was allowed. The ewes

Table 3.4 Composition and proximate analysis of supplements offered in mid pregnancy

	Feedblock	Pellet
	(Proportion on fresh weight basis)	
Barley	0.534	0.900
Urea	0.009	0.011
E C feed*	0.200	-
Sugar/molasses	0.030	0.040
Salt	0.100	-
Water	0.075	-
Mineral/vitamin mix	0.050	0.050
Dry matter (g/kg)	852	891
Ash (g/kg DM)	335	44
Nitrogen (g/kg DM)	28.3	26.0
Neutral-detergent fibre (g/kg DM)	76.7	272.3

* Molasses, distillers' dried solubles and other additives

were collected to the feeding point, if necessary, before the pellet was offered. The feedblocks were discoid in shape, 50 cm in diameter and 9 cm deep, and weighed 22.5 kg. Holes were drilled in the centre of each feedblock and threaded with a loop of string to facilitate weighing.

From 7 January 1980 one feedblock was placed at each of three sites spaced equidistantly along the vertical axis of the plot and when less than 4.0 kg remained, the remainder was replaced by a new block. From 3 to 8 February 1980, during a period of heavy snow, a fourth block was positioned at the lowest point of the plot where the animals were also being offered hay. From 9 February 1980, to control consumption, the frequency of replacement was reduced such that feedblocks were allowed to be totally consumed before being replaced. There were always two feedblocks weighing more than 4 kg available each day. Mean intake of feedblock was still greater than that required, and from 28 February to 7 March 1980 one new feedblock was offered every two days at each of the sites in turn.

Late pregnancy From 8 March 1980, ewes on all treatments were offered the same supplement in the form of a cob, 2 cm in diameter and approximately 3 cm long. The supplement (Sheep Breeders Rolls, SAI Ltd, Edinburgh) was formulated to have an ME value of

11 MJ ME/kg DM and to contain 140 g Crude Protein (CP)/kg DM. Cr_2O_3 was incorporated in the cob at a rate of 2 g/kg DM. The cobs were fed in troughs each morning as described above for Treatment D in mid pregnancy. To maintain the same moderate degree of under-nourishment in all treatments, all ewes were offered 140 g DM/day until 13 March 1980. Thereafter additional supplementary feeding was given to maintain a mean 3-OHB concentration in plasma of below 0.9 mM as predicted from a model of late pregnancy energy demand in the ewe (Russel, 1978). The model requires information on current and desired 3-OHB concentrations in plasma, ewe liveweight at mating, current liveweight, expected lambing rate and time to parturition. From relationships between energy status and 3-OHB concentrations in plasma, from predicted ME demands of the foetus and from the composition of the supplement, the model estimates the additional amount of supplement required for the next week to maintain 3-OHB concentrations in plasma at the prescribed level. The amounts of supplement given on each treatment are given in Section 3.1.3.

Management of Flock

Sheep handling facilities were constructed at two sites, one between plots 1 and 2 and a second between plots 3 and 4. Each handling area comprised pens sufficient to hold two groups of 50 ewes separately, a race and a covered area where ewes were weighed and other measurements were made.

Decision rules concerning periods of inclement weather from 4 January to 11 April 1980 were such that (i) hay was offered at 500 g/ewe/day if the proportion of the experimental area covered by snow was greater than 80% and (ii) the ewes would remain on the experimental area unless snow cover was 80% and further snow was forecast.

The ewes were removed from the experimental area on 11 April 1980. Ewes marked in the first week of mating were placed on improved pasture for lambing, and the remainder to an enclosed area of rough grazings. Ewes marked in the second week of mating remained on this until 20 April 1980, and ewes marked in the third week until 24 April 1980 before being moved onto improved pasture.

Barren ewes were removed on 24 April 1980. Supplementary feeding was given to ewes on rough grazings based on plasma concentrations of 3-OHB, to ewes on improved pasture before lambing, and for four weeks after lambing. The flock was grazed on improved pasture maintained at a sward surface height of 4 cm or greater until weaning on 18 August 1980.

Veterinary procedures were carried out as follows. Sixteen ewes per treatment were blood sampled on 15 January 1980 to check the copper status of the flock, which was found to be normal. All ewes were given a Covexin booster injection (Wellcome Foundation Ltd., London) on 18 March 1980, and all ewes were dosed with Panacur (Hoechst, U.K. Ltd., Hounslow Middlesex) on 11 April 1980. Lambs were dosed at 3-weekly intervals from 22 May until 18 August 1980 with Panacur. Ewes and lambs were dipped in July and September using Cooper Fly Dip (BHC) and Border Winter Dip (Cooper Agricultural Division, the Wellcome Foundation Ltd., Berkhamsted, Herts.)

Measurements

Ewe Performance Ewes were weighed once monthly from October to December 1979. Measurements of liveweight were made at two-weekly intervals in mid pregnancy, at three-weekly intervals in late pregnancy, on 22 May 1980, and at weaning on 18 August 1980. Ewe liveweights were recorded to the nearest 0.5 kg. All ewes were condition scored by the same operator according to the method of Russel, Doney and Gunn (1969) in mid and late pregnancy at the same time as when the ewes were weighed.

Lamb Performance All lambs were ear-tagged within 24 h of birth and their dam, date of birth, liveweight and sex recorded. Liveweight was measured using a pocket scale (Waymaster, P6K), and recorded to the nearest 0.1 kg. Still-births, deaths and probable causes of death were recorded. If a lamb was found dead, it was recorded as stillborn if a portion of the lung removed from the thorax did not float in water. Death of lambs alive at birth was classified as caused by starvation and/or exposure, or other causes if known. Death from starvation or exposure was characterised by absence of milk in the stomach and of any fat around the

abdominal viscera in very young lambs.

Male lambs were castrated on 22 May 1980, when lamb liveweight was recorded to the nearest 0.5 kg. The lambs were weighed at weaning on 18 August 1980.

Plasma metabolite concentration Sixteen ewes balanced for age, mating date and liveweight were randomly chosen from each treatment. Measurements of plasma concentrations of 3-OHB, non-esterified fatty acids (NEFA), glucose and urea were made on these ewes. Samples were taken weekly throughout mid and late pregnancy between 1000 and 1200 h and before morning feeding on all occasions when the ewes were offered supplements. Approximately 10 ml of blood was obtained by jugular vene puncture. The samples were centrifuged at 3000 r.p.m. for 20 minutes immediately on return to the laboratory. The plasma was drawn off and from 14 January to 4 March 1980, stored at -20°C to await analysis. From 11 March 1980, plasma samples were stored at +1°C and analysed for concentration of 3-OHB the following day. The plasma samples were then stored at -20°C to await the remaining analyses. The concentrations of 3-OHB and NEFA were determined by the methods of Zivin and Snarr (1973) and Patterson (1963) respectively. The concentrations of urea and of glucose were determined using a continuous flow analysis technique based on the methods of Marsh, Fingerhut and Miller (1965) and Gutteridge and Wright (1968).

Ruminal fluid concentrations Six animals (excluding two-year-old ewes) were chosen at random each week from the 16 ewes used for blood sampling to provide a sample of rumen fluid. The samples were obtained weekly at the same time as the blood samples. The rumen fluid sample was drawn into a collecting jar through a stomach tube using a hand pump modified for suction. On transfer to sample bottles 1 drop of concentrated H_2SO_4 was added per 5 ml of rumen fluid. The stomach tube and jar were rinsed and drained between samples. The samples were stored at -20°C to await analysis. They were then thawed and strained through muslin and then centrifuged at 15,000 r.p.m. The supernatant was drawn off and analysed as follows. Concentration of ammonia (NH_3) was determined by the method of Ellerker and Collinson (1971). The concentration of the volatile fatty acids (VFA), acetic, propionic

and butyric acids, was determined by the method of Cottyn and Boucque (1968). The sum of the concentrations of the 3 acids above was taken as the total VFA concentration and the concentration of each acid expressed as a proportion of the total VFA concentration.

Group intake of feedblock The feedblocks were weighed to the nearest 0.5 kg at approximately the same time each day, every second day.

Intake of supplements by individual ewes Since Cr_2O_3 was incorporated in the feedblock and in the pellet supplements, the daily intakes of the supplement were determined from the following equation:

$$\text{Daily supplement DM intake (g)} = \frac{\text{Daily faeces DM output (g)} \times \text{Cr concentration in faeces (mg/g DM)}}{\text{Cr concentration in supplement (mg/g DM)}}$$

Total faeces output was measured on 6 animals in Treatments C and D on four occasions in mid pregnancy and on 6 animals from all 4 treatments on one occasion in late pregnancy. The 6 animals were chosen from the subgroup of 16 animals per treatment which were used for blood sampling. The same sheep were used on each occasion where possible. The ewes were fitted with harnesses and collection bags, and faeces were collected between 1030 and 1200 h daily for five consecutive days for the first 3 sampling occasions, and on subsequent occasions for 4 days. The faeces were dried at 95°C for 48 h and then weighed. The concentration of Cr in the faeces was determined on a subsample taken from each day's faecal collection for each sheep and on samples of feedblock and pelleted supplements, which had been dried at 95°C for 24 h, by the method of Williams, David and Iismaa (1962).

To provide further information on the variability of intake of supplement from feedblocks, grab samples of faeces were taken from all sheep on Treatment C on four occasions during mid pregnancy. The samples were dried at 95°C and analysed for concentration of Cr as described above.

Herbage mass and in vitro OMD of A/F grassland Twenty quadrats (1.20 x 0.15 m) were cut to ground level from each plot from A/F grassland areas from 12 to 26 January 1980. All quadrats were cut by one operator. Owing to variable amounts of litter and considerable differences in the structure of the sward between those

areas dominated by bracken and those not, samples were bulked according to whether or not they had been cut from areas dominated by bracken. The material was thoroughly mixed and a 500 g subsample taken for separation into two categories, (i) A/F and other grasses, and (ii) other species, comprising mainly bracken, heather and Vaccinium myrtillus. The components of the subsamples were freeze dried and weighed. The herbage mass of A/F was determined from the dry weights of the bulked samples and the proportion of A/F in the sample. The freeze dried A/F subsamples were retained for determination of in vitro OMD values as described below.

Diet selection and in vitro digestibility of OM (OMD) of A/F in the diet Extrusa samples were obtained from oesophageal-fistulated sheep on 6 occasions on each of the 4 treatment plots over mid and late pregnancy when the animals were restricted to grazing the A/F grassland area. Four Scottish Blackface wethers (aged 3 years and weighing 60 kg) were used and were run in pairs on two plots on each of two consecutive days on each occasion. They had had previous experience of similar vegetation. They were given approximately 24 h to become accustomed to the plot and fellow sheep, and were held in the handling pens at the base of the treatment plot for 2 - 3 hours before sampling. The site of grazing where samples were obtained from the animals was recorded. When not being used the animals were kept on sheltered grazing and offered hay and concentrates.

The extrusa samples were frozen immediately and stored at -20°C until freeze dried. The freeze-dried material was separated into three categories, (i) A/F and other grasses (ii) heather and (iii) other species including Vaccinium myrtillus, Pteridium aquilinum and Eriophorum spp. The weight of components was recorded and where there was sufficient material, determinations of in vitro OMD were carried out on samples ground through a 1 mm sieve according to the method of Tilley and Terry (1963), as modified by Alexander and McGowan (1965). A set of A/F standards of known in vivo digestibility were used.

Statistical analyses

Analyses of variance were carried out on the data using the EDEX statistical package (Hunter, Patterson and Talbot, 1979)

Ewe performance data Variation associated with age, mating date and bearing type were considered as treatment factors. In pregnancy, means were adjusted for differences between treatments in bearing type and in lactation for differences in rearing type. Where F values were significant, student's 't' test was applied to treatment means.

Lamb birthweight data A χ^2 test was carried out to test for differences between treatments in the number of barren, single- or twin-bearing ewes. Data for single and twin lambs were then subjected to analysis of variance. Variation associated with sex of lamb, age of ewe, date of birth and length of gestation were removed as treatment factors together with variation associated with treatment effects and treatment x age interactions. The treatment means were adjusted for differences between treatments in the numbers of male and female lambs, date of birth and age structure of the lambing flock (due to different incidence of barren ewes within age groups in the different treatments) where the F value was significant or nearly so. Variation associated with length of gestation was considered as the interaction between mating date and lambing date. No attempt was made to adjust for this because, although lamb birthweight was correlated with gestation length, differences in the latter might have been associated with treatment effects. However, there was no significant difference between treatments in gestation length. Since the variance for single and twin birthweights were found to be similar, the sets of data were combined using the mean twin birthweight, and sex of lambs (male (M) or female (F)) and single/twin was coded M, F, MM, MF, FF. The data were analysed as above. Differences between treatments were examined using a Student's 't' test.

Lamb liveweight data Data were analysed by analysis of variance with age of ewe, sex of lamb, date of birth, rearing type and experimental treatment as treatment factors and treatment means were adjusted for the above mentioned non-experimental side effects where significant.

Plasma metabolite concentration data A split-plot design was used, with sheep as units and sampling occasions (weeks) as

subunits. Variation caused by age, bearing type (N) and time to parturition (D) was removed as treatment factors. Where N and D removed a significant amount of the variation or where F values were large, treatment means were adjusted for imbalance in these factors. Where the data yielded a skew distribution, it was transformed using a $\log_e$ transformation before statistical analyses were carried out. Corrected means were obtained as follows:

$$\text{Corrected mean} = \text{antilog}_e \left(\begin{matrix}\text{mean of n} \\ \text{values}\end{matrix} \log_e + \frac{1.15(n-1)}{n} \text{RMS} \right)$$

where RMS = residual mean square from analysis of variance and n = number of observations. Two analyses were carried out on each plasma variable. The first included all mid pregnancy sampling occasions from 10 January to 4 March 1980, and the second all late pregnancy sampling occasions from 11 March to 8 April 1980. Where F values were significant, appropriate 't' tests were carried on treatment, week and treatment x week means. Errors for transformed data are expressed as antilog_e (average SE of difference between means x relevant t value).

The transformation and/or adjustments for each plasma variable are summarised below:

Plasma variable	Mid pregnancy	Late pregnancy
3-OHB	Trans-$\log_e$, adjust D	Trans-$\log_e$, adjust D, N
NEFA	Trans-$\log_e$	adjust D, N
Glucose		Trans-$\log_e$ adjust D, N
Urea		Trans$\log_e$

Ruminal fluid concentration data Treatment and week of sampling were analysed as treatment factors. Rumen NH_3 concentration data yielded a skew distribution and was transformed before analysis ($\log_e$). Corrected means were obtained as for plasma metabolite concentration data.

Intake of supplement data A multiple rank correlation coefficient, the Kendall coefficient of concordance (W) was calculated to assess the degree of correlation between 3 or more complete sets of rankings of intake (Siegel, 1956). Where W was small but statistically significant, rank correlations were calculated between pairs of ranks (Spearman's coefficient (r_s), as described by Steel and Torrie (1960) to determine how the rankings in a series were related. Coefficients of variation were estimated as described by Steel and Torrie (1960).

In vitro OMD of A/F in the diet data Variability associated with sheep, week and treatment were considered as treatment factors. Treatment and treatment x week means were adjusted for sheep differences.

RESULTS (Section 3.1.3)

Herbage mass and in vitro OMD of A/F grassland

Estimates of herbage mass and in vitro OMD values of harvested A/F material for each of the four plots are given in Table 3.5.

Table 3.5 Herbage mass and in vitro OMD values of A/F grassland at the start of the experiment

Plot	Treatment	Herbage Mass (kg DM/ha)	in vitro OMD
1	A	1450	0.38
2	C	2400	0.35
3	B	1220	0.36
4	D	880	0.34

There are no errors attached to the herbage mass values owing to the method of bulking the samples. However in Experiment 4 error estimates were obtained and if these are applied to the data in Table 3.5 it would appear that Plot 2 had a higher herbage mass of A/F than the other plots at the start of the experiment. There were no large differences in in vitro OMD between plots.

Intake of supplement in mid pregnancy

There were no supplement refusals in mid pregnancy on Treatment

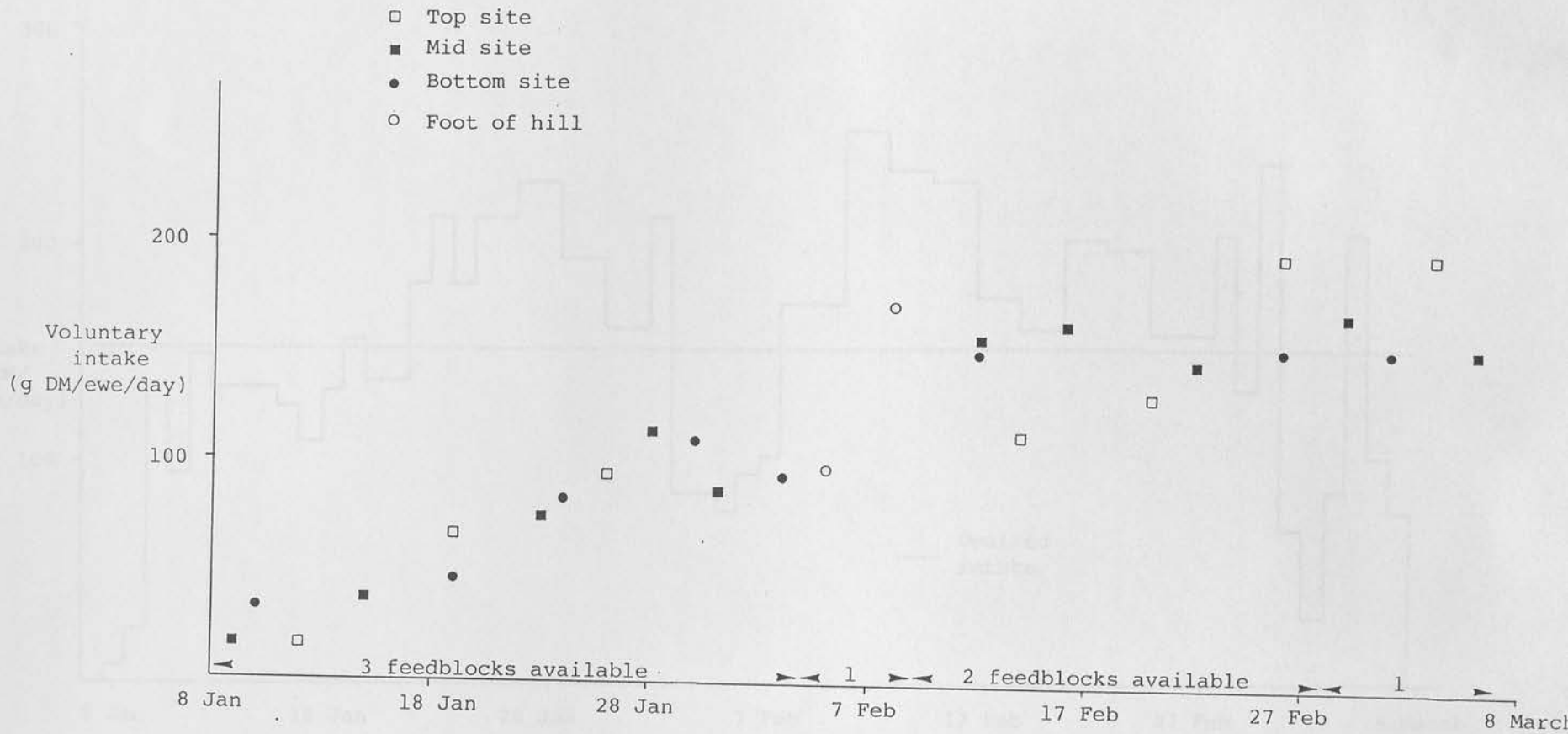


Figure 3.5 Voluntary intake of feedblock at 4 sites during midpregnancy by ewes on Treatment C in Experiment 1.

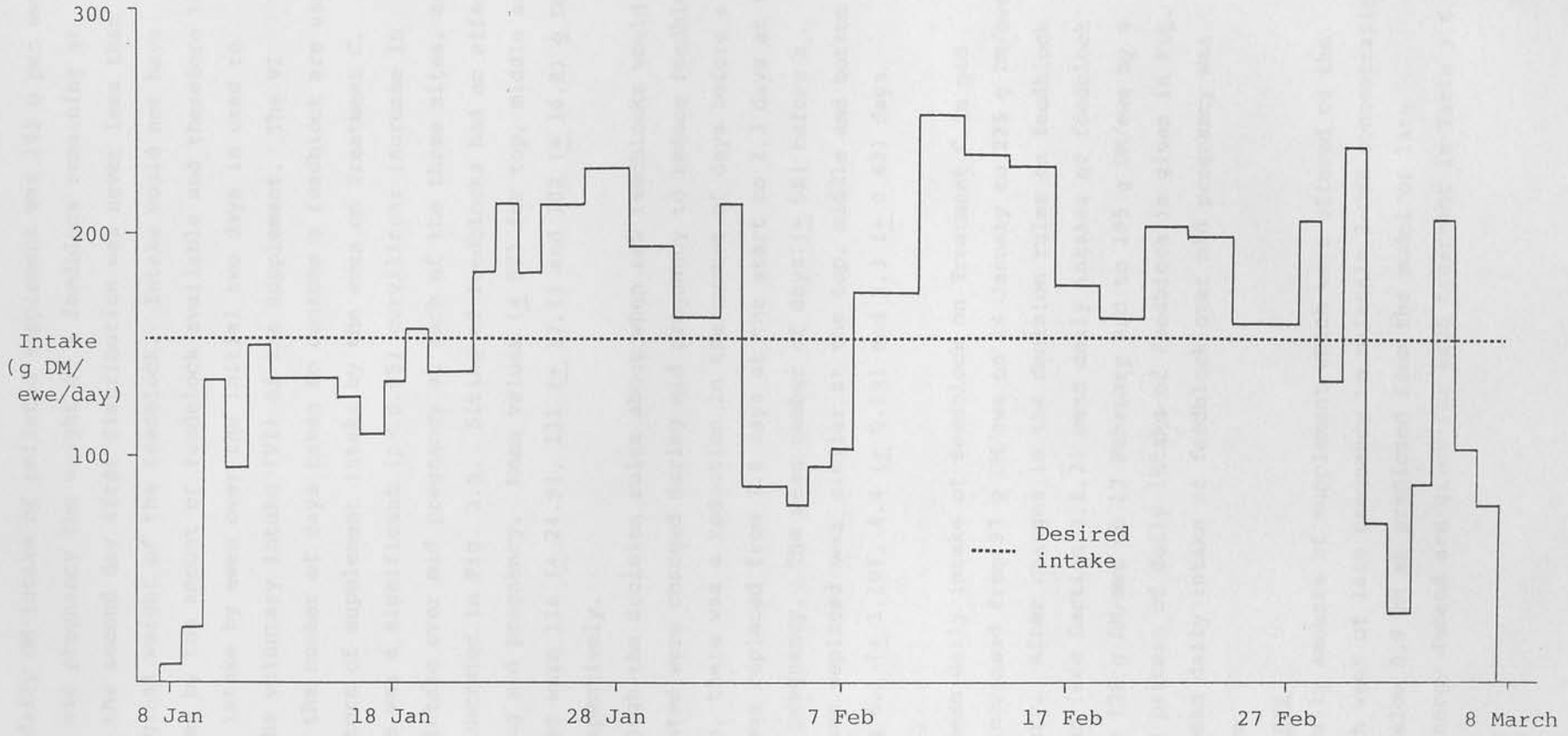


Figure 3.6 Pattern of intake of feedblock in mid pregnancy by ewes on Treatment C in Experiment 1

D and the daily DM intake of pelleted supplement was 143 g per ewe. Throughout mid pregnancy the weight of a feedblock remaining at the end of the second day after distribution was never less than 0.1 of the original weight of the feedblock. Intake would not have been limited by the amount of feedblock available and therefore the mean daily intake by ewes over the initial two days is used to describe the voluntary intake (VI) of the supplement. The VI values and the number of days taken to consume a feedblock are used as descriptors of supplement intake by the ewes on Treatment C.

There was a significant ($p < 0.05$) curvilinear increase in voluntary intake over mid pregnancy at each of the three sites, and this is illustrated in Fig. 3.5. Siting of feedblocks had no effect on VI during mid pregnancy. Mean values (± SE) for top, middle and bottom sites were 116 (± 24.9), 111 (± 17.4) and 102 (± 16.8) g DM/ewe/day respectively.

Although the decision rules about when new feedblocks would be distributed were changed during mid pregnancy to reduce feedblock consumption, there was a reduction in the number of days before a feedblock was replaced from 7.6 days at the start to 2.3 days at the end of mid pregnancy. The mean number of days (± SE) before a feedblock was replaced was similar at the top, middle and bottom sites being 6.1 (± 1.10), 4.4 (± 0.19) and 5.3 (± 0.82) days respectively.

The mean daily intake of feedblock on Treatment C in mid pregnancy increased from 97 g DM/ewe on 14 January to 225 g DM/ewe by 8 February. After changes in the decision rules on feedblock distribution (see Section 3.1.2) mean daily intakes of feedblock declined to 179 g DM/ewe on 17 February and to 195 g DM/ewe by 6 March. The pattern of daily intake of feedblock is given in Fig. 3.6. The mean daily intake of feedblock over mid pregnancy was 179 g DM/ewe.

Late pregnancy

The daily amounts of supplement which were offered to the ewes in each week of late pregnancy to maintain 3-OHB concentration in plasma below 0.9 mM as predicted from the model of late pregnancy energy demand are given for each treatment in Table 3.6.

Table 3.6 Amounts of supplement (g DM/ewe/day) offered to ewes in each week of late pregnancy

Week beginning	Treatment A	B	C	D
14 March	140	140	145	140
20 March	175	175	175	175
27 March	245	175	175	280
3 April	245	210	175	280

The daily amounts of supplement offered per ewe for Treatments A, B, C and D from 8 March to 10 April were 6.6, 5.8, 5.6 and 7.1 kg respectively. There were no refusals of supplement.

Intake of hay

During snow cover 9.1 kg DM/ewe was offered on each treatment.

Ewe performance

The pattern of ewe liveweight over pregnancy for the treatments is illustrated in Fig. 3.7. The mean liveweight (± SE) in November 1979 was 57 (± 0.37) kg. Ewe liveweight fell over mid pregnancy and rose again in late pregnancy. A loss in liveweight was recorded in early lactation, partly attributed to the loss of the foetus and associated tissues at lambing, before a recovery phase in late lactation and after weaning. This pattern is typical of that found with this system of management. Table 3.7 gives the ewe liveweight changes over the production cycle in which the experiment was carried out.

Table 3.7 Ewe liveweight changes (g/ewe/day) (Adjusted means)

Period	Treatment A	B	C	D	Ave SE
12 November - 4 January (Mating to start of expt)	- 47	- 58	- 52	- 58	6.9
4 January - 29 February (mid pregnancy)	- 111	- 111	- 6	- 60	6.6
29 February - 11 April (late pregnancy)	+ 77	+ 49	- 13	+ 56	8.5
11 April - 22 May (early lactation)	- 26	- 16	- 67	- 68	13.8
22 May - 18 August	+ 54	+ 52	+ 54	+ 33	5.9

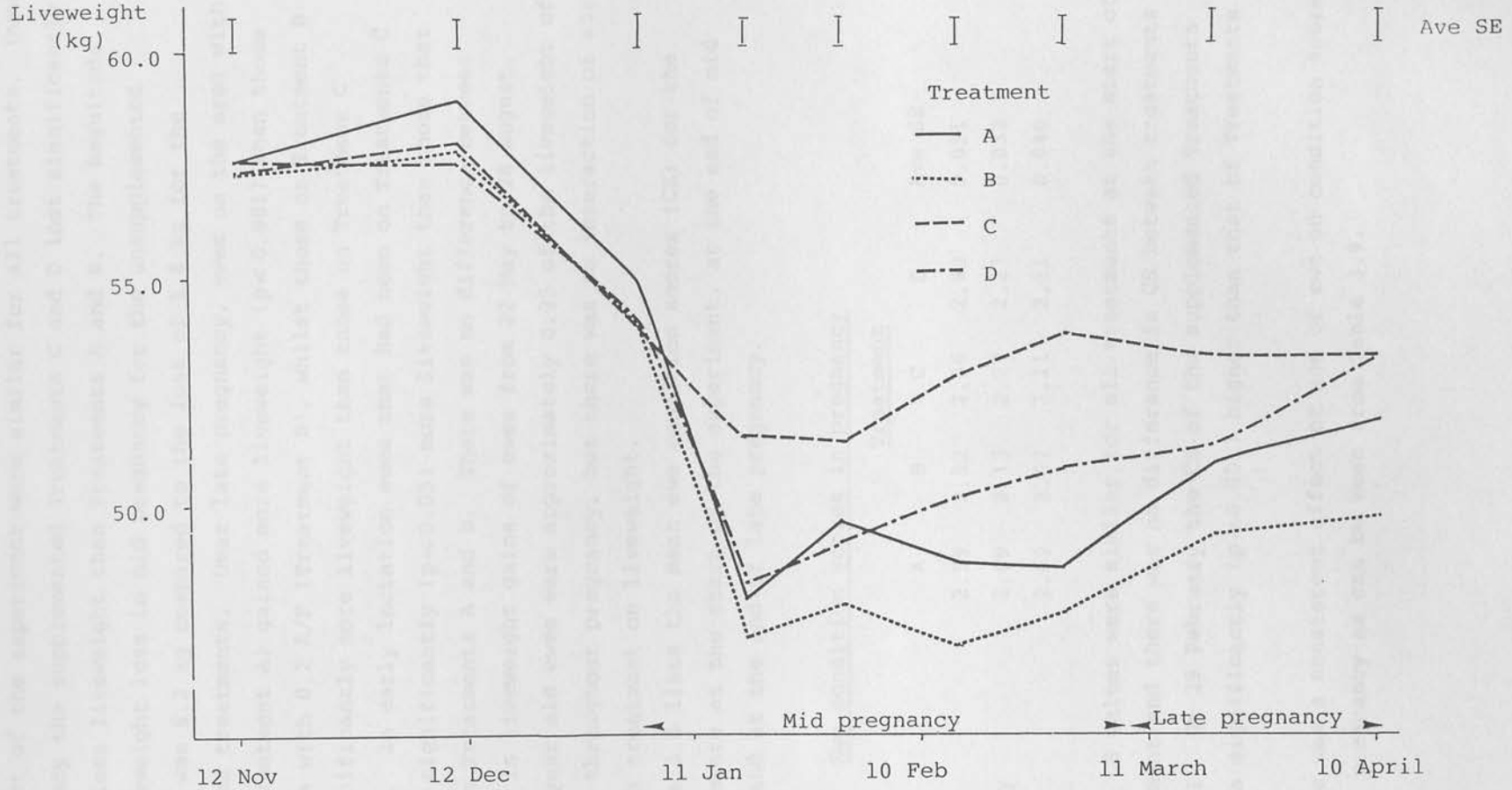


Figure 3.7 Pattern of ewe liveweight over pregnancy in Experiment 1

The liveweight changes between the start of mating and the commencement of the experiment were similar for all treatments. Over mid pregnancy the supplemented Treatments C and D lost significantly ($p<0.001$) less liveweight than Treatments A and B. The magnitude of the liveweight loss in mid pregnancy for the unsupplemented treatments was 6.2 kg compared to the loss of 1.8 kg for the supplemented treatments. Over late pregnancy, ewes on the area with 0.4 A/F (Treatment A) gained more liveweight ($p< 0.001$) than those on the area with 0.2 A/F (Treatment B), whilst those on Treatment B gained significantly more liveweight than those on Treatment C ($p<0.001$). In early lactation ewes that had been on Treatments C and D lost significantly ($p<0.05$) more liveweight than those that had been on Treatments A and B. There was no difference between treatments in liveweight gains of ewes from 22 May to 28 August.

Two-year old ewes were approximately 0.93 of the liveweight of older ewes throughout pregnancy, but there was no interaction of age of ewe with treatment on liveweight.

Table 3.8 lists the mean ewe condition scores (CS) for the four treatments at the start of the experiment, at the end of mid pregnancy and at the end of late pregnancy.

Table 3.8 Ewe condition scores in pregnancy

Date	Treatment				
	A	B	C	D	Ave SE
4 January	2.99	2.92	2.86	2.93	0.051
29 February	2.09	2.13	2.27	2.27	0.033
11 April	2.09	2.07	2.11	2.11	0.040

Mean CS values were similar for all treatments at the start of the experiment and there was no difference in CS between treatments on 11 April. On 29 February the CS of the supplemented Treatments C and D was significantly ($p<0.001$) higher than that of Treatments A and B.

There was a consistent effect of age of ewe on condition score throughout pregnancy as can be seen from Table 3.9.

Table 3.9 Effect of age of ewe on condition score

Date	Age of ewe (years)				
	2	3	4	5	Ave SE
4 January	3.08	2.91	2.88	2.78	0.051
29 February	2.28	2.18	2.16	2.11	0.034
11 April	2.18	2.11	2.06	1.98	0.040

On 4 January 2-year old ewes had a significantly ($p < 0.001$) higher score than older ewes. The CS of all groups fell over mid pregnancy but the CS of 2-year-old ewes was still significantly higher ($p < 0.05$) on 29 February than that of older ewes. By 11 April the mean CS had fallen to 2.09 for all age groups. However, the 2-year-old ewes were still in significantly ($p < 0.05$) better condition than the 4 and 5-year-old ewes and 3-year-old ewes. There was no significant interaction between age of ewe and treatment for ewe condition score at any stage of pregnancy. Ewes bearing twins, single and barren ewes had CSs of 2.03, 2.12 and 2.25 (Ave SE 0.042) respectively at the end of pregnancy.

Individual values for ewe performance data are listed in Appendix Table A1.

Lamb performance

The number of lambs at birth and on 22 May together with the number of ewes which were barren is listed for each treatment in Table 3.10

Table 3.10 Ewe and lamb performance

	Treatment			
	A	B	C	D
No. of ewes pre-lambing	49	50	48	49
No. of barren ewes	7	7	6	7
No. of lambs born	68	65	61	65
No. of lambs born alive	66	61	60	60
No. of lambs alive at 22 May	55	53	54	56

There was no significant difference between the treatments in the number of barren ewes or the number of lambs born. The overall proportion of barren ewes was 0.14 and the overall lambing rate was 1.25. Of the ewes classed as barren, 2 ewes from each of Treatments

A, C and D either aborted or produced stillborn decomposing foetuses at term. 7 lambs, 1 lamb and 3 lambs born to ewes on Treatments A, C and D respectively were considered to have died from exposure and starvation within the first week of life. No lambs born to ewes on Treatment B died of exposure or starvation, but of the 5 which died, 3 weighed 1.6 kg or less at birth and were given artificial heat and feeding. The overall weaning rate was 1.07.

The birthweights of single and twin lambs for each treatment are given in Table 3.11 together with the combined data for single and twin lambs. For twin lambs there was a significant ($p < 0.05$) effect of age of ewe, sex of lamb and date of birth on birthweight, but there was no interaction of any of these parameters with treatment. Male lambs were 0.3 kg heavier than female lambs, lambs out of gimmers were 0.7 kg lighter than those of older ewes, and lambs born in the first week of lambing were 0.4 kg lighter than lambs born in later weeks. For single lambs none of these effects explained a significant amount of variation.

Table 3.11 Lamb birthweights (adjusted means)

	Treatment				
	A	B	C	D	Ave SE
Single lamb (kg)	3.51	3.93	4.20	3.77	0.211
Twin lamb (kg)	2.99	2.79	3.15	3.24	0.086
All lambs (kg)	3.23	3.33	3.61	3.53	0.103

There was no significant treatment effect on the birthweights of single lambs. Twin lambs from the supplemented treatments in mid pregnancy (Treatments C and D) were significantly ($p < 0.001$) heavier than twin lambs on the unsupplemented treatment (Treatment B). There was no effect of proportion of A/F grassland on birthweights of twin lambs. Since the variances of twin and single lambs were shown to be homogeneous, the data for both lamb types were combined. For the combined data, the birthweights of the lambs from the supplemented treatments were 0.24 kg greater ($p < 0.07$) than those from the unsupplemented treatment in mid pregnancy.

Growth rates of lambs from birth to weaning are given in Table 3.12. There were significant effects of age of ewe, sex of lamb and rearing type ($p < 0.05$) on lamb growth rates from birth to 22 May.

Table 3.12 Lamb liveweight gains (g/d) during lactation (Adjusted means)

Dates	Treatment				
	A	B	C	D	Ave SE
Birth to 22 May	280	261	289	276	7.3
22 May to 18 August	183	191	184	176	5.8

Lambs reared by 4-year-old ewes gained 23 g/day more than lambs reared by ewes of other ages. Male lambs gained 17 g/day more than female lambs, and single reared lambs gained 79 g/day more than twin reared lambs. When treatments are compared, lambs reared by ewes on Treatment C had significantly ($p < 0.05$) greater liveweight gains than those on Treatment B. This was reflected in mean lamb liveweights at 22 May of 11.6, 11.0, 12.2 and 11.5 kg (Ave SE $\pm$ 0.25) for lambs reared by ewes on Treatments A, B, C and D respectively. Lambs reared by ewes on Treatment C were significantly ($p < 0.01$) heavier than lambs reared by ewes on Treatments B and D.

From 22 May to 18 August, rearing type explained only a significant ($p < 0.05$) amount of the variation in lamb liveweight gains. Single reared lambs gained 19 g/day more than twin reared lambs. There was no significant effect of treatment on liveweight gains to weaning or on weaning weight. Mean weaning weight ($\pm$ SE) was 27.8 ($\pm$ 0.29) kg.

Individual values for lamb performance data are listed in Appendix Table A2.

Intake of supplements by individual ewes on Treatments C and D in mid pregnancy

The mean DM intake by ewes of supplements estimated from measurements of faecal output and Cr concentrations in feedblock and faeces and the coefficient of variation in DM intake in each of the 4 measurement periods in mid pregnancy are given in Table 3.13. Individual values are listed in Appendix Table A3. Although the 6 ewes used to make these measurements were selected to be typical of the whole group, the mean DM intake of feedblock on the first 3 occasions by those ewes on Treatment C was 0.5 of the estimate derived for the whole group from feedblock weighing. The mean DM intake of the pelleted supplement by the 6 ewes on Treatment D was

similar to that of the whole group for each period. There were significant ($p<0.01$) multiple rank correlations of 0.77 and 0.78 between ranks of intake on successive sampling dates for Treatments C and D respectively.

Table 3.13 DM intakes of supplements by ewes (DMI) and coefficients of variation of DM intake of supplements (CV) in mid pregnancy (Means of 6 observations)

Week beginning	22 January	5 February	19 February	4 March
Treatment C				
DMI (g/day)	54	52	60	126
SE	4.8	3.8	3.5	8.9
CV(%)	54	44	36	42
Treatment D				
DMI (g/day)	120	174	115	160
SE	5.8	6.4	7.0	7.4
CV(%)	29	22	37	28

The coefficient of variation of DM intake of supplements was generally higher for ewes ingesting feedblock (44%) than for those receiving the pelleted supplement (29%). The variability in daily output of faeces concentration of Cr and daily output of Cr in the faeces was also higher for ewes on Treament C than on Treatment D as can be seen from the coefficients of variation given in Table 3.14.

Table 3.14 Coefficients of variation in daily OM output of faeces (CV_{DMF}), concentration of Cr in faecal DM (CV_{Cr}) and daily output of Cr in the faeces (CV_{CrF}) by ewes on Treatments C and D (Means of 6 observations

Treatment		Period beginning 22 January	5 February	19 February	4 March
C	CV_{DMF} (%)	* 37	26	40	27
	SE	7.5	3.6	6.4	4.3
	CV_{Cr} (%)	* 53	35	44	33
	SE	11.2	6.0	5.5	6.6
	CV_{CrF} (%)	* 75	45	61	42
	SE	14.4	8.0	4.9	7.7
D	CV_{DMF} (%)	11	17	27	16
	SE	5.3	3.4	6.8	4.3
	CV_{Cr} (%)	28	20	19	26
	SE	4.3	3.8	5.1	6.6
	CV_{CrF} (%)	29	18	36	27
	SE	10.0	5.3	4.8	2.3

* Mean of 5 observations

Intake of feedblock by ewes on Treatment C in mid pregnancy from faecal Cr concentration

On 21 January, 16 days after the introduction of feedblocks, 0.11 of the ewes sampled had no Cr in their faeces and were thus considered to have ingested no supplement. On the subsequent dates all faecal samples contained Cr.

There was no consistent difference in faecal Cr concentration between age groups of ewes. Two-year-old ewes had faecal Cr concentrations (215 mg/kg DM) which were significantly ($p < 0.05$) higher than older ewes (109 mg/kg DM) on 1 February, but on 26 February 3-year-old ewes (312 mg/kg DM) had significantly ($p < 0.05$) higher faecal Cr concentrations than ewes of other age groups (232 mg/kg DM).

Mean Cr concentration in the faeces increased over mid pregnancy, presumably reflecting in part an increase in supplement intake, and the coefficient of variation in Cr concentration in the faeces decreased during mid pregnancy (see Table 3.15).

Table 3.15 Concentration of Cr in faeces, and coefficient of variation (CV) in Cr concentration and estimates of supplement intake

	Sampling date			
	21 January	1 February	15 February	26 February
No. of ewes sampled	47	43	37	43
Cr concentration (ppm)	84	136	217	254
CV (%)	64	68	54	39
Estimated supplement intake (g DM/day)	38	71	115	150

Estimates of supplement intake were made by applying the mean faecal output value, for the period nearest the sampling date derived from the group of 6 ewes, to the mean Cr concentration value and the values are also given in Table 3.15. Estimates of supplement intake were 0.5 of those obtained by weighing feedblocks. Individual values are given in Appendix Table A4. The frequency distribution of intakes by ewes on the 4 occasions in mid pregnancy are given in Fig 3.8.

There was a significant ($p < 0.05$) multiple rank correlation (W) of 0.42 between rankings of chromium concentration in the faeces for each sampling date. Significant rank correlations were found for rankings for the following on adjacent sampling dates: 1 and 15 February $r_s = 0.41$ ($p < 0.05$) and 15 and 26 February $r_s = 0.62$ ($p < 0.001$).

Intake of supplement in late pregnancy

The mean daily DM intakes of supplement by the groups of 6 ewes in each treatment were similar to that of the mean daily amounts of supplement per ewe being offered for Treatments A and B, were higher for Treatment C and considerably lower for Treatment D. The coefficients of variation of supplement DM intake were higher on those treatments where the ewes had not previously received supplement (see Table 3.16) Individual values are given in Appendix Table A5.

Table 3.16 DM intake (DMI) of pelleted supplement by ewes in late pregnancy in week beginning 27 March and coefficient of variation (CV) of DMI of supplement (Means of 6 observations)

	Treatment			
	A	B	C	D
DMI (g/day)	232	184	210	197
SE	64.9	44.7	85.7	34.2
CV (%)	69	60	52	43

Ruminal fluid concentration in mid pregnancy

Table 3.17 gives the mean concentrations of rumen NH_3, total VFA and proportion of acetic, propionic and butyric acids over all sampling occasions in mid pregnancy. Appendix Table A6 lists the mean values

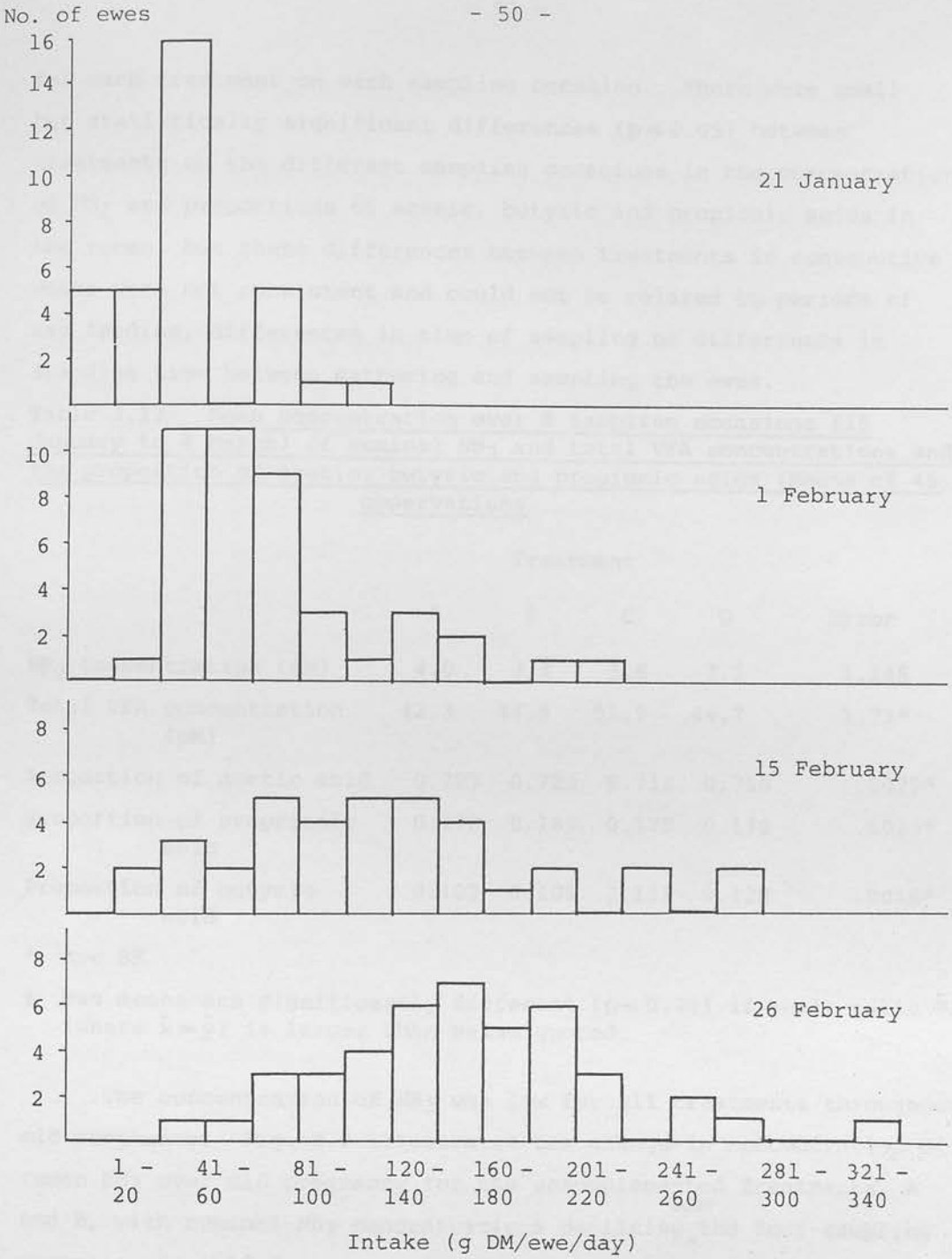


Figure 3.8 Frequency distribution of supplement intake measured on 4 occasions in mid pregnancy by ewes on Treatment C in Experiment 1.

for each treatment on each sampling occasion. There were small but statistically significant differences ($p < 0.05$) between treatments on the different sampling occasions in the concentration of NH_3 and proportions of acetic, butyric and propionic acids in the rumen, but these differences between treatments in consecutive weeks were not consistent and could not be related to periods of hay feeding, differences in time of sampling or differences in standing time between gathering and sampling the ewes.

Table 3.17 Mean concentration over 8 sampling occasions (15 January to 4 March) of ruminal NH_3 and total VFA concentrations and the proportion of acetic, butyric and propionic acids (Means of 48 observations

	Treatment				
	A	B	C	D	Error
NH_3 concentration (mM)	4.0	3.4	3.8	3.5	1.14§
Total VFA concentration (mM)	42.3	44.5	51.9	44.7	1.73*
Proportion of acetic acid	0.727	0.723	0.712	0.710	.0029*
Proportion of proprionic acid	0.172	0.169	0.175	0.170	.0023*
Proportion of butyric acid	0.102	0.108	0.113	0.120	.0016*

* Ave SE

§ Two means are significantly different ($p < 0.05$) if their ratio $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is larger than value quoted.

The concentration of NH_3 was low for all treatments throughout mid pregnancy. Fig. 3.9 illustrates the change in concentration of rumen NH_3 over mid pregnancy for the unsupplemented Treatments, A and B, with ruminal NH_3 concentrations declining over the four sampling occasions from 15 January to 5 February, and then rising. Comparing the mean concentrations of NH_3 for all mid pregnancy sampling occasions, Treatment A had values which were 0.6 mM higher ($p < 0.05$) than Treatment B, but there was no difference between supplemented Treatments C and D and Treatment B.

Treatment C had a significantly higher ($p < 0.001$) total VFA concentration than Treatments A, B and D. The proportion of acetic acid was greater ($p < 0.001$) on Treatments A and B than on Treatments

C and D, but the magnitude of the differences was only 0.02 of the mean value.

Supplemented treatments had significantly ($p < 0.001$) higher proportions of butyric acid than non-supplemented treatments and Treatment D had significantly ($p < 0.001$) higher values than that of Treatment C. There was no significant difference between treatments in the proportion of propionic acid.

Ruminal fluid concentrations in late pregnancy

The mean concentration of rumen NH_3, total VFA and the proportions of acetic and propionic and butyric acids for each treatment for each of the 3 sampling occasions in late pregnancy are listed in Appendix Table A7. There was no significant interaction between treatment and sampling occasion for any of the variables, and the combined treatment means are listed in Table 3.18.

Table 3.18 Ruminal concentration of NH_3, total VFA and the proportion of acetic, propionic and butyric acids (Means of 24 observations)

	Treatment				
	A	B	C	D	Ave SE
NH_3 (mM)	4.44	2.71	2.63	3.10	1.167 §
Total VFA (mM)	46.7	46.5	42.2	45.6	1.72
Proportion of acetic acid	0.700	0.724	0.724	0.720	0.0039
Proportion of propionic acid	0.179	0.166	0.164	0.171	0.0028
Proportion of butyric acid	0.121	0.111	0.112	0.109	0.0022

§ two means differ ($p < 0.05$) if their ratio $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is greater than the value quoted.

The mean concentration of NH_3 for each sampling occasion for Treatments A and B is shown in Fig. 3.9. Rumen NH_3 concentrations were consistently higher in late pregnancy for Treatment A (0.40 A/F) than for treatments where A/F was 0.20 of the area (B, C and D) resulting in a mean NH_3 concentration for the period of 1.6 times greater than that of Treatments B, C and D ($p < 0.001$). The mean rumen NH_3 concentration in late pregnancy was significantly ($p < 0.001$)

higher for Treatment D than C although the magnitude of the difference was only 0.47 mM. There was no significant difference between concentrations of total VFA or proportions of acetic, butyric or propionic acids.

Plasma concentrations in mid pregnancy

Table 3.19 gives the mean concentrations of plasma 3-OHB, NEFA, glucose and urea for each treatment and for each sampling occasion in mid pregnancy. Appendix Table A8 lists the mean values for each treatment on each sampling occasion. There were small significant ($p<0.05$) interations between treatment and sampling date for each variable, but apart from the plasma urea values, no attempt is made to describe them as it was not possible to ascribe an interpretation to them.

Table 3.19 Mean concentration over 9 sampling occasions (10 January to 4 March) of plasma urea, 3-OHB, NEFA and glucose

	Treatment				
	A	B	C	D	Error
Urea (mM)	2.58	2.04	2.09	1.89	0.147*
3-OHB (mM)	0.37	0.37	0.38	0.34	0.107§
NEFA (mM)	814	759	720	688	1.132§
Glucose (mM)	3.14	3.19	3.15	3.10	0.058*

* Ave SE

§ two means are significantly different ($p<0.05$) if their ratio $\bar{x}/\bar{y}$ (where $\bar{x}>\bar{y}$) is greater than the tabulated values.

	Date of sampling									
	10 Jan	15 Jan	21 Jan	29 Jan	5 Feb	12 Feb	19 Feb	26 Feb	4 Mar	Error
Urea (mM)	2.34	3.07	2.37	1.51	1.44	1.79	2.14	2.39	2.32	0.078*
3-OHB (mM)	0.28	0.31	0.35	0.36	0.30	0.43	0.38	0.48	0.42	1.072§
NEFA (mM)	705	951	699	600	659	734	816	800	826	1.096§
Glucose (mM)	3.35	3.20	3.19	3.23	2.99	3.19	3.08	2.94	3.02	0.040*

* Ave SE

§ two means are significantly different ($p<0.05$) if their ratio $\bar{x}/\bar{y}$ (where $\bar{x}>\bar{y}$) is greater than the tabulated values.

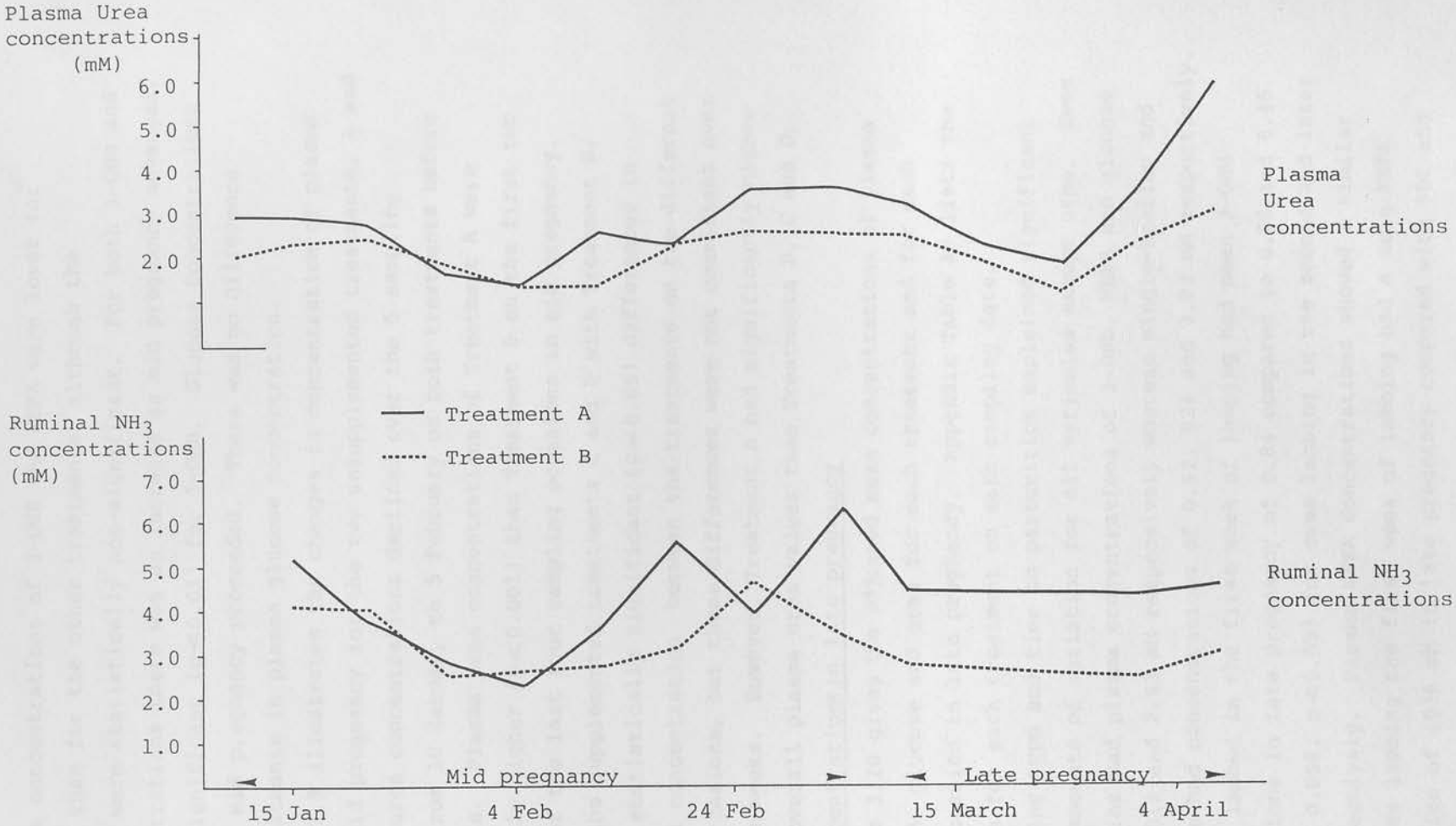


Figure 3.9 Changes in plasma urea and ruminal NH_3 during pregnancy for Treatments A and B in Experiment 1. Ave SE for comparing treatments for NH_3 in late pregnancy and urea in mid pregnancy are 0.70 and 0.21 respectively. Treatment means of NH_3 in mid pregnancy and urea in late pregnancy differ ($p < 0.05$) where their ratio (> 1) > 1.46 and 1.31 respectively.

Plasma concentrations of 3-OHB and NEFA were lower for Treatment D than for the other treatments, although the differences were statistically non-significant. For both 3-OHB and NEFA concentrations there was an increase as mid pregnancy advanced, which was significant ($p<0.01$) for 3-OHB. Glucose concentrations declined as mid pregnancy proceeded. There was no difference between treatments in plasma glucose concentration.

Fig. 3.9 illustrates the changes in concentration of plasma urea over mid pregnancy for the two unsupplemented treatments, A and B. Plasma urea concentrations declined over the 5 sampling occasions from 10 January to 5 February on both treatments before rising again. Plasma urea concentrations of Treatment A were significantly higher ($p<0.001$) than Treatment B on the first two and three of the last four sampling occasions in mid pregnancy. Comparing the supplemented treatments C and D with Treatment B, there were statistically significant ($p<0.05$) differences in plasma urea concentration between the treatments on the different sampling occasions, but these differences were not consistent over consecutive weeks. However, Treatment A had significantly higher ($p<0.05$) overall plasma urea values than Treatments B, C and D.

Plasma concentrations in late pregnancy

Table 3.20 gives the adjusted mean concentrations of plasma 3-OHB, NEFA, glucose and urea for each treatment and for each sampling occasion in late pregnancy. Appendix Table A9 lists the mean values for each treatment on each sampling date.

Bearing type and time to parturition explained significant ($p<0.05$) amounts of variation for all variables except urea. Ewes bearing twins had plasma concentrations of 3-OHB, NEFA and glucose of 0.81, 1018 and 2.83 mM respectively whereas single-bearing and barren ewes had concentrations of 0.52, 824 and 3.03 mM respectively. Ewes which lambed in the first week of lambing had mean 3-OHB concentrations in late pregnancy of 0.84 compared to 0.66 and 0.46 mM (Ave SE 0.058, $p<0.05$) for ewes lambing in the second and later weeks respectively. Plasma NEFA concentrations showed a similar trend; ewes lambing the first week of lambing had a mean NEFA concentration of 1036 mM in late pregnancy compared with 908 and

803 mM (Ave SE, 45.5) for those lambing in the second and later weeks respectively. Plasma glucose concentration increased with time to parturition. Mean plasma concentrations were 2.78, 2.91 and 3.16 (Ave SE, 0.063, $p<0.05$) mM for first, second and later weeks respectively.

Table 3.20 Adjusted mean concentrations of plasma 3-OHB, NEFA, glucose and urea for each treatment and for each sampling occasion in late pregnancy (means of 80 observations)

	Treatment				
	A	B	C	D	Error
3-OHB (mM)	0.63	0.59	0.59	0.64	1.12§
NEFA (mM)	931	931	853	909	36.9*
Glucose (mM)	3.21	2.88	3.00	2.71	0.057*
Urea (mM)	2.97	2.00	2.11	1.93	1.23§

	Date of sampling					
	11 March	18 March	25 March	1 April	8 April	Error
3-OHB	0.54	0.54	0.64	0.68	0.63	1.084§
NEFA (mM)	892	804	885	995	958	27.2*
Glucose (mM)	2.88	2.89	3.20	2.86	2.91	0.042*
Urea (mM)	2.33	1.97	1.49	2.38	3.74	1.101§

* Ave SE

§ Two means significantly different ($p<0.05$) if their ratio $\bar{x}/\bar{y}$ (where $\bar{x}>\bar{y}$) is greater than the quoted value.

There was no effect of treatment on the concentration of plasma 3-OHB or NEFA. Both 3-OHB and NEFA concentrations rose towards the end of pregnancy. There was a significant ($p<0.001$) effect of treatment on plasma glucose concentration; Treatment A (0.40 A/F grassland) being higher than the other (0.20 A/F grassland) treatments, and Treatment C being greater than Treatment D.

Plasma urea concentrations in Treatment A (2.97 mM) were significantly ($p<0.01$) greater than the other treatments (2.02 mM). Plasma urea concentrations declined until 25 March and then increased. Fig 3.9 illustrated the changes for Treatments A and B.

In vitro OMD of A/F in the diet

In vitro OMD values of A/F from extrusa samples from oesophageal fistualted sheep were highly variable, but there was no indication that the herbage mass of an area from which the diet was selected was an important source of this variation. A mean value for Treatments B, C and D where A/F covered 0.20 of each plot is listed in Table 3.21 for each sampling occasion, together with values for Treatment A where A/F covered 0.40 of the area.

In vitro OMD values declined from January to mid March and then increased. There was no consistent difference between Treatments A and B in in vitro OMD of the diet of A/F selected.

Table 3.21 In vitro OMD of extrusa samples (± SE) where A/F covered 0.40 and 0.20 of the area

Date		Proportion of A/F in the plot	
		0.40	0.20
17 & 18 January	OMD	0.42(1)	0.50(4)
	SE	-	0.006
14 & 15 February	OMD	0.50(2)	0.41(3)
	SE	0.028	0.034
27 & 28 February	OMD	0.48(2)	0.47(8)
	SE	0.044	0.004
12 & 13 March	OMD	0.37(2)	0.38(5)
	SE	0.028	0.019
26 & 27 March	OMD	0.45(2)	0.45(2)
	SE	0.033	0.075
9 & 10 April	OMD	0.60(2)	0.48(8)
	SE	0.010	0.016

Figures in brackets are no. of values

DISCUSSION (Section 3.1.4)

The overall performance of the flock was comparable with the previous 2 years when a two pasture system (Eadie, 1978) had been operated. The proportion of barren ewes (0.14 compared with 0.11 in the previous 2 years) and the lambing rate (1.25 compared with 1.18 in the previous 2 years) were similar. The weaning rate of 1.07 was the same as the mean of the previous 2 years. The pattern of ewe liveweight in pregnancy and lactation was also similar to that observed previously and to that described by Russel (1971) for other hill environments. However, there were differences with previous years which cannot be ascribed to treatment effects, particularly in relation to a higher mating liveweight and condition score than would be commonly found in this or other hill environments and in the maintenance of liveweight until mid December. Thereafter the ewes lost liveweight at an extremely rapid rate of 143 g/day until the start of the experiment. Mild weather in early autumn followed by a cold frosty period which influenced herbage availability on the improved pasture is the likely explanation.

Proportion of A/F in sward

There was no advantage of the greater proportion of A/F on lamb birthweight. Initial herbage allowances of A/F were 290 kg DM/ewe for Treatment A and 122 kg DM/ewe for Treatment B, demonstrating a 2.38 fold difference. However, the *in vitro* digestibility of A/F on offer (0.37) on both treatments was only sightly higher than the value of 0.35 obtained by Eadie and Black (1968) for the dead component of winter A/F. Consequently there would have been only a small amount of live A/F material (< 0.05) of potentially higher digestibility in the sward in January, and this would have decreased before herbage growth recommenced in late March. Although the *in vitro* OMD value of A/F of the diet selected was 0.45 in January, indicating that the selection of live material was taking place, it declined to 0.38 by mid March. However, no difference was observed between Treatments A and B in mid pregnancy in *in vitro* OMD values of the diet selected, although the standard errors were relatively high. Ruminal NH_3 concentrations also support the conclusion that there was little difference between the treatments in the quality

of the A/F selected, assuming that potential differences in the intake of heather and other species would have had less influence on ruminal NH_3 concentrations than the intake of A/F. There was no difference between the treatments from the first date of measurement (11 days after the start of the experiment) until mid February. Plasma urea values were significantly higher for Treatment A than for Treatment B on the first sampling occasion (6 days after the start of the experiment) and remained higher until the 17th day of the experiment. The higher plasma urea values could have been due to the diet containing higher quality A/F since plasma glucose, NEFA and 3-OHB concentrations suggested similar rates of tissue mobilisation. However, in the rest of mid pregnancy there was no difference between Treatments A and B in plasma urea values. The small differences in _in vitro_ OMD values of the A/F selected in the diet, ruminal NH_3 and plasma urea concentrations are reflected in the lack of difference between the two treatments, liveweight or body condition change of the ewes in mid pregnancy.

Ewes on Treatment A gained more liveweight (1.2 kg) in late pregnancy, even when the values were statistically adjusted for the greater number of lambs carried by ewes on Treatment A. The greater liveweight gained by ewes on Treatment A could not be attributed to greater foetal growth rates as there were also no differences between treatments in the birthweights of singles or twins. There was also no apparent fat-sparing effect of better nutrition for ewes on Treatment A as there was no difference between the treatments in condition score at the start or end of late pregnancy. However, Russel, Doney and Gunn (1968), in describing the changes in maternal tissue of Blackface ewes grazing hill pastures over pregnancy, suggested that fat is lost first from the subcutaneous depots before internal depots, and bone in particular. Over the first four months of pregnancy ewes losing 0.17 of their premating body weight lost 0.67 of subcutaneous fat reserves, compared with 0.19 in late pregnancy. For bone, corresponding figures were 0.01 and 0.24 respectively. Thus there might have been a fat-sparing effect of better nutrition for Treatment A compared with Treatment B which was undetectable using condition score as a measure of fatness.

Evidence for better levels of nutrition in late pregnancy are the higher *in vitro* OMD values of A/F selected in the diet for Treatment A (0.60) than Treatment B (0.40) in early April and the higher rumen NH_3 and plasma urea concentrations. However, using the 3-OHB concentrations the model of energy demand in late pregnancy estimated that Treatment A required 11% more supplement than Treatment B to equate energy need.

It is concluded that differences in initial herbage allowance of A/F, which contain over 0.95 dead material, would have required to have been greater than the two fold difference observed in this experiment to influence nutrition in mid pregnancy and to increase birthweights of lambs.

Effect of form of supplement

Ewes offered the pelleted supplement lost more liveweight in mid pregnancy than those offered feedblock. Two reasons for this can be put forward. Firstly there was a difference in the amount of A/F available. Although the areas of A/F were equal there was a 3 fold greater allowance of A/F on Treatment C than D because of the differences in herbage mass (Treatment C, 2400 kg DM/ha; Treatment D, 800 kg DM/ha) associated with differences in bracken cover between plots. Secondly, the ewes on Treatment C consumed 17% more supplement (15.3 MJ ME) than was desired over mid pregnancy, and the higher VFA concentrations throughout mid pregnancy presumably reflect this. Most of the liveweight loss on Treatment D occurred in the first 2 weeks of mid pregnancy when the diet was changed from a perennial ryegrass pasture/hay diet to an A/F heather diet. In wethers a change from a perennial ryegrass pasture to a heather diet results in a liveweight loss of 3 kg within a few days, presumably due to gut-fill changes (Milne, personal communication). The implication is that ewes on Treatment C consumed a diet containing more A/F in the early part of mid pregnancy, thus not incurring such a liveweight loss associated with gut-fill. Liveweight changes over the rest of mid pregnancy and the CS changes for the two treatments were similar over mid pregnancy, suggesting that the first reason given may have been of primary importance.

In late pregnancy ewes on Treatment D received 16.5 MJ ME

more supplement than those on Treatment C to equate energy needs according to the model of energy demand in late pregnancy. The higher ruminal NH_3 and total VFA concentrations observed for Treatment D than C may reflect this. There was no difference in lamb birthweight between Treatments C and D, indicating that the method of feeding the supplement had no gross effects on performance.

Effect of supplementary feeding

Supplementation in mid pregnancy reduced loss in liveweight by 78g/day and of CS by 0.17 in mid pregnancy. In late pregnancy CS changes were small and there were no consistent differences in liveweight or CS changes between supplemented and unsupplemented mid pregnancy treatments. Birthweights of twin lambs of supplemented treatments were increased by 14.7%. Birthweights of single lambs were not influenced by mid pregnancy supplementation. No clear evidence to support the hypotheses developed in Section 2 on possible mechanisms for responses in birthweight to mid pregnancy supplementation can be brought forward. Because of the difficulty in interpreting the energetics of changes in CS as pregnancy advances - which were referred to earlier in Section 3.1.4 - caution is required in interpreting the higher CS of supplemented ewes at the end of mid pregnancy and the similar CS values of both supplemented and unsupplemented ewes at the end of late pregnancy. It is, however, possible to interpret them as indicating a fat-sparing effect of supplementation in mid pregnancy for subsequent utilisation in late pregnancy. Based on the results of indoor experiments with cold stored heather and A/F, the supplement should have provided additional absorbed energy, because of the additive effects of the supplement to herbage intake (Milne, Christie and Russel, 1979; Milne, Spence and McCormack, unpublished) and absorbed protein (Mayes and Lamb, 1982). The rumen and blood parameters measured do not provide support for these contentions. Although there was a shift to a higher propionate:acetate fermentation in the rumen on the supplemented treatments, there was little evidence of increased total VFA concentrations which were low, but of the same order as found with supplemented heather diets given indoors (Milne et al, 1979). There was also no effect of supplementation on plasma glucose, NEFA or 3-OHB concentrations.

The low ruminal NH_3 (3 mM) and plasma urea (3 mM) concentrations were not elevated by supplementation, implying that the available N in the rumen was insufficient for the available carbohydrate supply. However, these interpretations must be considered in relation to the time of sampling of rumen fluid and plasma. This was prior to feeding of the pellet in Treatment D, when the differences between supplemented and unsupplemented treatments in rumen and plasma parameters would be least (see Milne et al, 1979). With Treatment C, however, the feedblock was observed to be ingested in the period 2 - 3 hours before samples were taken, and this had little apparent effect on rumen or blood parameters.

There are no previous reports of ruminal NH_3 and VFA concentrations on ewes grazing in winter. Sykes and Field (1974) and Sykes and Russel (1979) reported similar patterns of change in plasma concentrations of glucose and urea to those reported here both in mid and late pregnancy for heather-dominant hill grazings. In late pregnancy, plasma urea concentrations remained low (4.5 mM), reflecting in part the low ruminal NH_3 concentrations and the higher efficiency with which protein is utilised in late pregnancy (Robinson and Forbes, 1967). NEFA, 3-OHB and glucose concentrations were influenced by foetal load and date of parturition in the manner indicated by Russel (1978) and Mellor (1983). The parameter values were such that these authors would have predicted that the ewes were nourished in late pregnancy to produce adequate birthweights. However, the birthweights of twin lambs were low, such that, based on the mortality curve over the last 10 years for this flock (Sibbald, personal communication; see Fig. 4.1), 0.25 of twin lambs would not have been expected to survive to weaning. On the basis of the 3-OHB concentrations observed, the late pregnancy energy demand model used, predicted that only small amounts of supplement were required. The relationships used in the model were developed in controlled indoor experiments (Russel, 1978). Such factors as the nature of the roughage, the type of supplement and the ingestive behaviour of the ewe in relation to the time of blood sampling (Bowden, 1971; Mayes and Milne, 1983) may influence the relationship. In experiments such as this one where it is wished to vary

nutrition in mid pregnancy but not in late pregnancy feeding, predetermined levels of supplement in late pregnancy may provide an easier interpretation of the results.

Supplement intake

The ewes on Treatment C consumed more feedblock as mid pregnancy proceeded until voluntary intake of feedblock was considerably greater than the desired intake. Although there was a curvilinear relationship between voluntary intake and time, voluntary intakes observed were probably a consequence of the way in which feedblocks were distributed. The number of feedblocks available at any one time was reduced from three to one during mid pregnancy, and voluntary intake could have been higher if 2 or 3 feedblocks had been available until the end of this period. Kendall (1977) noted that intakes were higher when 2 feedblocks were offered to steers rather than 1. When the frequency of feedblock replenishment is low, high intakes following fresh placement would make intakes on the remaining days low, leading to highly variable intakes between feedblock allocations. As the feedblocks were weighed only every second day throughout most of mid pregnancy, it is likely that this masked greater variation in intake than was observed in this experiment. Between-day variation in intake as affected by feedblock allocation is considered worthy of further investigation, not only in mid pregnancy, but also in late pregnancy where the supplement may be supplying 0.4 of the daily nutrient intake of the ewe.

There was no effect of siting of the feedblock on voluntary intakes, as the natural movement of the sheep covered the entire plot. However, casual observations suggested that the presence of feedblocks had considerable consequences for the grazing behaviour of the ewes which would merit more detailed investigation. When only one feedblock was present at the top or bottom of the plot, the ewes appeared to spend a greater proportion of their time in that half of the plot.

It was intended to compare hand-feeding and block-feeding of the ewes in terms of performance and nutritional parameters. Thus it was important to limit intakes of feedblock to the desired

levels such that effects of blocks per se could be examined. There were two alternative procedures: (i) to set out the allowance of feedblock for a certain number of days, accept the high variability in daily intakes which might ensue, and attempt to quantify the effects, (ii) to supply smaller quantities of the supplement more frequently. This would enable the measurement of the consequences of a desired pattern of intake, even if it subsequently proved necessary to investigate further the factors affecting feedblock intake under these conditions. The second option was chosen, which meant also that feedblock was on offer over the entire period of measurement of intakes of individual ewes. However, highly variable daily intakes might be associated with a greater range in individual ewe intakes, since decreasing the time the supplement is available might increase competition around the feedblock.

Intakes of supplement measured individually on ewes on Treatment D were similar to those obtained from the group intake measurements. Those on Treatment C were 0.50 those estimated from group intakes. The most likely explanation is that insufficient feedblocks were sampled for Cr concentration to obtain an accurate estimate. This should not affect the validity of the coefficient of variation values. The variability in supplement intake was higher for block-feeding than hand-feeding. The coefficients of variation for hand-feeding in mid pregnancy were similar to those obtained by Foot and Russel (1973) and Foot, Russel, Maxwell and Morris (1973) for group-fed hill sheep, and Kendall, Hemingway and Ducker (1980) for groups of Greyface ewes fed similar amounts, and with similar trough space, but higher values were obtained in late pregnancy, particularly for those groups which had not received supplement in mid pregnancy. The higher coefficients of variation in late pregnancy 3 weeks before parturition may have been because weaker ewes and those carrying twins were less competitive feeders, and this would have been aggravated by the faecal collection apparatus. It is possible that providing the supplement as cobs increased coefficients of variation. Kendall et al (1980) found coefficients of variation of less than 30% when cobs were fed to

sheep on the ground, but the levels of intake were very high.

Coefficients of variation in supplement intake by ewes on Treatment C decreased over mid pregnancy. This was a function of all ewes eventually ingesting feedblock and of an increase in mean intake of supplement. The significant rank correlations found between different sampling dates suggests that the variability in supplement intake was not a chance effect, and that, if the causal factors could be determined, the high coefficients of variation observed could be reduced.

For both Treatments C and D the variability in supplement intake was associated with similar variability in DM faecal output, Cr concentration in faeces and Cr output in faeces. There was no correlation between mean daily Cr concentration in faeces and the corresponding DM faecal output, implying that variation in Cr concentration in faeces was associated with intake of Cr in the supplement. Variability in daily faecal output may occur as a result of variation in herbage and feedblock intakes, endpoint errors in daily faecal collections and loss of faeces from collection bags. However, where the latter was suspected at the time of handling the ewes, those values for faecal output were discarded.

Variation in the concentration of Cr in faeces may occur as a result of diurnal variation in excretion associated with the number and timing of meals together with differences in timing of faeces collection or differences in daily intake of the supplement. Circumstantial evidence for this is that the variability between daily output of Cr for sheep on Treatment C was higher than for Treatment D, although the daily pattern of Cr concentration could not be related to availability of the feedblock on Treatment C. The implication of these findings to the use of faecal grab samples to estimate supplement intake is that grab sample data will give an acceptable estimate of the overall variation in intake. However, the concentration of Cr in one small sample of faeces will be an unreliable guide to the average intake of the ewe over a longer period.

It is therefore not surprising that, in spite of the wide variability in supplement intake and the apparent consistency of

ranking of intakes, there was no relationship between mean intake and liveweight change in mid pregnancy or the birthweight of single or twin lambs. Similarly, no relationships were found between estimated supplemented intakes and the concentration of plasma and ruminal variables, apart from plasma urea concentration which was significantly ($p < 0.05$) correlated with estimates of intake of feedblock by the 16 ewes blood sampled in Treatment C. Variables such as ruminal NH_3 concentration may change rapidly over a few hours in relation to feedblock intake, whilst plasma urea concentrations will reflect intakes over longer periods such as a day.

Summary

There was no improvement in ewe liveweight change in mid pregnancy or in the birthweight of lambs, with a 2.4 fold increase in the initial allowance of A/F. Provision of a supplement supplying 1.5 MJ ME and 3 g $N_{\Lambda}^{/day}$ either as feedblock or hand fed pellets reduced liveweight and condition score losses and increased the birthweight of twin lambs.

EXPERIMENT 2: the effects of supplementation in mid pregnancy, with reference to feedblock placement, and of the herbage allowance of A/F on a heather dominant hill on ewe and lamb performance.

INTRODUCTION (Section 3.2.1)

Increasing the allowance of A/F species by a factor of 2.38 to ewes grazing a predominantly heather hill in mid pregnancy did not improve ewe or lamb performance in Experiment 1. Evidence from ruminal NH_3 and plasma urea concentrations suggested that any advantage which the ewes on the higher allowance may have had in their ability to select a better quality diet in January was quickly lost and not regained until the end of late pregnancy. One possible explanation is that the relatively small proportion of green material in the sward in January may limit the opportunity for selection irrespective of herbage allowance. Alternatively a higher herbage allowance difference may allow greater amounts of nutrients to be ingested such that responses in ewe and lamb performance can be obtained. This latter hypothesis was tested by making a comparison between high and low allowances of A/F where the size of the difference in herbage allowance was increased to a factor of almost 4. The high allowance was obtained by grazing an area containing 0.40 A/F at a stocking rate of 1.2 ewes/ha and the low allowance by grazing an area containing 0.20 A/F at the same stocking rate of 2 ewes/ha used in Experiment 1.

Although the 3-OHB concentrations in plasma remained low throughout late pregnancy in Experiment 1, the birthweights, particularly of twin lambs, were low on all treatments. Thus ewes in late pregnancy may not have been adequately nourished in Experiment 1, with consequent implications for the interpretation of the responses obtained to mid pregnancy supplementation. A comparison was therefore made between ewes receiving supplement and no supplement where fixed levels of supplementation were given in late pregnancy.

The nitrogen to energy ratio and the amount of supplement offered in mid pregnancy in Experiment 1 was chosen on the basis of previous experimental results (Milne et al, 1979; Mayes and Lamb, 1982; Milne and Spence, unpublished) to enhance conditions in the rumen for optimal roughage digestion and, together with the nutrient

supply from the supplement, increase the nutrients available to the ewe. Although the level of supplement used in Experiment 1 (1.5 MJ ME and 3 g N per day) significantly reduced liveweight losses, these losses were still high, particularly with the hand fed supplement treatment. There is, therefore, a case for increasing the amount of nutrients given by supplement. Supplementation did not appear to increase ruminal NH_3 concentrations in Experiment 1 even on the feedblock treatment where some animals were known to consume feedblock before ruminal samples were taken. An increase in the proportion of N, as urea, in the supplement could lead to an increase in microbial protein synthesis in the rumen and thus in the amounts of amino acids absorbed. Consequently the amount and composition of the supplement was changed from that of Experiment 1 such that the supplement provided 1.8 MJ ME and 6 g N per day.

It was observed in Experiment 1 that the siting of the feedblock appeared to influence the grazing behaviour of the sheep, but not the pattern of intake of the feedblock, although this might have been associated with the pattern of feedblock placement. Arnold and Bush (1968) reported differences in intake of trough fed supplements when the supplement was placed in different area of a 40 ha paddock grazed by 80 Merino weaners, but there is no information on the effect of siting on feedblock intake in extensive hill situations in the U.K. Similarly there is no information on the responses in grazing behaviour of ewes to siting of feedblocks on hill areas, nor on the nutritional consequences of changes in grazing behaviour. Kilgour (1974) suggested that siting of supplements could be used as a means of grazing control on arid pastures which are often overgrazed close to water supplies. Siting of self-help supplements might provide a useful means of grazing control in extensive hill situations in the U.K., particularly in the case of heather which is sensitive to grazing and treading (Gimingham, 1972). The effects of feedblock siting on heather and A/F were, therefore, studied on 2 mid pregnancy supplementation treatments. The behavioural aspects of the study have been reported briefly by Eddison, Muetzelfeldt and Wood-gush (1982) and the nutritional aspects are reported here. Comparisions were made when feedblocks were placed on heather

and A/F areas within the same plot to avoid any between-plot variation. A control period in early pregnancy where all ewes were unsupplemented was followed by 2 periods when feedblocks were placed on one vegetation type followed by the other. To take into account the possibility that the grazing behaviour of the ewes could be influenced by the order of siting itself or by the herbage allowance of A/F which might decline as mid pregnancy proceeded, the sequence of block placement on vegetation types was reversed in a further comparison on another area.

In Experiment 1 feedblocks were allocated such that supplement was always available. In commercial usage feedblocks are likely to be allocated once weekly, and this experiment such a procedure was adopted during mid pregnancy with measurements being made of the pattern of daily intake. The irregular pattern of daily group intakes observed in Experiment 1 suggests that there may be problems associated with the use of feedblocks in late pregnancy as the form of supplement. This was examined in this experiment by supplying the supplement by feedblock to all ewes in late pregnancy, by quantifying the pattern of intake obtained and by examining the consequences to ewe nutrition and performance.

MATERIALS AND METHODS (Section 3.2.2)

The experiment was undertaken on the Birnie hirsel at HFRO's Glensaugh Research Station using the same four plots which had been laid out in 1979 as described in Section 3.1.2.

Treatments

The following four treatments were imposed on 179 Scottish Blackface ewes, from 15 December 1980 to 6 March 1981:

A No supplementary feeding during early pregnancy or mid pregnancy, ewes grazing an area with 0.4 A/F grassland at a stocking rate of 1.2 ewes/ha.

B No supplementary feeding during early pregnancy or mid pregnancy, ewes grazing an area with 0.2 A/F grassland at a stocking rate of 2.1 ewes/ha.

C No supplementary feeding in early pregnancy. Supplementary feeding by feedblock in mid pregnancy, ewes grazing an area with 0.2 A/F grassland at a stocking rate of 2.1 ewes/ha.

Feedblocks were positioned according to the sequence: A/F grassland, Calluna vegetation.

D No supplementary feeding in early pregnancy. Supplementary feeding by feedblock in mid pregnancy, ewes grazing an area with 0.2 A/F grassland at a stocking rate of 2.1 ewes/ha. Feedblocks were positioned according to the sequence: Calluna vegetation, A/F grassland.

Ewes on Treatment A grazed plot 1, and Treatments B, C and D were allocated to plots 3, 2 and 4 respectively (see Fig. 3.4). The early pregnancy period was from 15 December 1980 to 10 January 1981 (median days 21 to 47 of pregnancy). The amounts of supplement allocated to Treatments C and D in mid pregnancy provided a mean daily intake of 1.8 MJ ME and 6 g N per ewe. The same amounts of supplementary feeding were offered to each treatment in late pregnancy in the form of feedblocks.

Animals

The age distribution of the 179 ewes and gimmers used in the experiment at October 1980 is given in Table 3.22

Table 3.22 Age distribution of ewes at October 1980

Age (years)	No. of animals
2	53
3	49
4	39
5	27
6	11

From 18 August until 18 October 1980 all the ewes were grazed on the 4 hill experimental plots with the same stocking rate on each plot. Thereafter they grazed on improved pasture, being joined with rams fitted with marker crayons on 18 November. Marked ewes were recorded weekly until 15 December when ewes were allocated treatments and moved to the experimental plots together with one ram per plot. The ewes were allocated to the 4 treatments in groups balanced for age, mating date and liveweight. Treatments A, B, C and D contained 30, 50, 49 and 50 ewes respectively. Rams were removed on 30 December . The number of ewes mated each week from 18 November to 15 December is given in Table 3.23.

Table 3.23 The number of ewes mated in each week after introduction of rams

Age of ewe (years)	Week 1	2	3 and 4
2	24 (2)*	21 (0)	7 (0)
3	31 (0)	17 (0)	1 (0)
4	25 (0)	15 (0)	-
5	16 (1)	10 (1)	1 (0)
6	8 (1)	3 (0)	-

* Figures in brackets are returns to service.

Feeds

Mid pregnancy. The feedblocks were made by Rumenco Ltd., to meet the experimental specifications. They were of the same dimensions and weight as those described in Experiment 1. The composition of the feedblocks together with their proximate analysis is given in Table 3.24.

Table 3.24 Composition and proximate analysis of supplements offered

	Feedblock (proportion on fresh weight basis) Mid pregnancy	Late pregnancy
Barley	0.500	0.433
Urea	0.040	0.010
E C Feed	0.200	0.200
Water	0.075	0.075
Salt	0.100	0.100
Mineral/vitamin mix	0.050	0.020
Sugar	0.030	0.060
Soya bean meal	-	0.100
Dry matter (g/kg)	829	817
Ash (g/kg DM)	335	281
Nitrogen (g/kg DM)	35.7	26.3
Neutral-detergent fibre (g/kg DM)	64.6	106.3

To meet the daily intakes of N and ME, the ewes needed to be offered 170 g DM of feedblock per ewe. Three blocks were provided once weekly and were sited approximately 5 m apart in the middle of A/F grassland or Calluna vegetation. From 11 January to 7 February 1981 feedblocks for Treatment C were placed on A/F grassland, and for Treatment D on Calluna vegetation. From 8 February to 7 March, feedblocks for Treatment C were placed on Calluna vegetation and for Treatment D on A/F grassland. From 1 to 7 March, an extra feedblock was positioned at the foot of the plot for Treatments C and D as snow cover was greater than 80%, and the ewes on all treatments were offered hay at the foot of their plots. Feedblocks were weighed daily except during this week, and data on feedblock supply for 1 to 7 March are not included in the results. Feedblock remaining at the end of any week was removed.

Late pregnancy. Ewes on all treatments were offered the same supplement in the form of feedblock. The supplement (Rumevite Extra Energy, Rumenco Ltd.) was formulated to provide an ME content of 11.5 MJ ME/kg DM and to contain 150 g CP/kg DM. Cr_2O_3 was incorporated into the feedblock at 2 g/kg DM. The feedblocks were positioned twice weekly and were available on Calluna vegetation and A/F grassland simultaneously. The blocks on A/F were positioned at the foot of the plot.

For the weeks beginning 7, 14, 21 and 28 March and 4 April, 3,4,4,5 and 6 feedblocks respectively were offered per week to ewes on Treatments B, C and D. To achieve the same intakes of 164, 213, 213, 271 and 328 g DM/ewe/day as for Treatments B, C and D in each of the above weeks, ewes on Treatment A were offered 2, 2.5, 2.5, 3 and 3.5 feedblocks respectively. The ewes were removed from the treatment plots on 8 April 1981, put on improved pasture for lambing and given a pelleted supplement. The supplement (Ewemax cubes, SAI Ltd, Edinburgh) was formulated to provide an ME content of 11 MJ ME/kg DM and to contain 140 g CP/kg DM. The ewes were offered 340 g DM/ewe/day until 8 May, when the ration was reduced to 130 g DM/ewe/day. Supplementation ceased on 12 May 1981.

Management of flock

Sheep handling facilities, veterinary procedures and decision rules concerning periods of inclement weather were the same as

those described in Section 3.1.2. After lambing the lactating ewes were grazed on improved pasture until weaning on 28 August 1981.

Measurements

Ewe performance. Ewes were weighed once monthly from October to December 1980. From 15 December to 6 January, ewes were weighed at weekly intervals and thereafter at 2-weekly intervals until 8 April 1981. The ewes were also weighed on 26 May and 28 August 1981. Ewe liveweights were recorded to the nearest 0.5 kg. All ewes were condition scored according to the method of Russel, Doney and Gunn (1969) by one operator from 15 December 1980 to 8 April 1981 at the same time as the ewes were weighed.

Lamb performance. Lambs were ear tagged within 24 h of birth and the same records taken as described in Section 3.1.2. Male lambs were castrated on 26 May when lamb liveweights were recorded to the nearest 0.5 kg. Lambs were also weighed at weaning on 28 August.

Plasma metabolite concentrations. Blood samples were taken from 16 ewes per treatment weekly from 22 December 1980 to 6 April 1981 as described in Section 3.1.2. A subsample of 16 ewes balanced for age, mating date and liveweight was chosen from each treatment group. The samples were analysed for plasma concentrations of 3-OHB, NEFA, glucose and urea.

Ruminal fluid concentrations. Ruminal fluid was obtained from the same 8 animals weekly at the same time as blood samples were obtained as described in Section 3.1.2. The 8 animals (excluding 2-year-old ewes) were chosen at random from the sub-group of 16 used to provide blood samples. Samples were stored and analysed for NH_3 concentration as described in Experiment 1 (see Section 3.1.2).

Group intake of feedblock. All feedblocks were weighed daily throughout mid and late pregnancy to the nearest 0.5 kg at approximately the same time each day.

Intake of supplement by individual ewes in mid pregnancy on Treatments C and D. Daily intakes of supplement were determined by the method described in Section 3.1.2. The intakes of supplement by 10 animals (from the sub-group of 16 used to obtain blood samples)

were measured on 2 occasions in mid pregnancy, once when the feedblocks were placed on one type of vegetation and once when placed on the other. The same 10 animals were used on both occasions for Treatment C, but only 7 animals were sampled twice for Treatment D.

Herbage mass and in vitro OMD of A/F grassland

Fifty quadrats were cut to ground level from areas of A/F grassland in each plot from 10 to 19 December 1980. The samples were bulked and handled as described in Section 3.1.2. Freeze-dried A/F material was retained for determination of in vitro OMD values.

Diet Selection and in vitro OMD of A/F in the diet

Extrusa samples were obtained from 6 oesophageal-fistulated Scottish Blackface wethers on 9 occasions over mid and late pregnancy in each of Treatments A and B. The animals were grazed as a group and restricted to grazing A/F grassland at the foot of each plot from 23 December onwards. They were sampled on two consecutive days, and were given approximately 24 hours to become accustomed to each treatment plot before being sampled. The animals grazed alternate plots on day 1 of each measurement period. When not grazing the experimental area the animals were kept on sheltered grazing and offered hay and concentrates. The extrusa samples were handled as described in Section 3.1.2. Few of the samples required any separation to remove vegetation which was not A/F material.

The wethers (aged 3 years) were prepared with oesophageal fistulae at least 6 months before the experiment started and had had experience as lambs in grazing similar vegetation. Their liveweight at the start of the experiment was 55 kg.

Statistical analyses

Analyses of variance for the ewe performance, lamb birthweight and lamb performance data were conducted in a similar manner to that described in Section 3.1.2.

The plasma concentration data were divided into 2 sets, one relating to early and mid pregnancy (22 December to 2 March 1981), and one to late pregnancy (9 March to 6 April 1981). For the first set, mean values for each treatment were calculated for 3 periods, and the period means were subunits in the split plot analysis, where, as in Experiment 1, sheep were the whole units. Period 1 involved

3 sampling occasions from 22 December to 5 January, and periods 2 and 3, 4 sampling occasions in the first half of mid pregnancy from 12 January to 2 February, and the latter half of mid pregnancy from 9 February to 2 March, respectively. Where F values were significant, appropriate t tests were carried out on treatment, period and treatment x period means which were adjusted for treatment imbalance of ewe bearing type and time to parturition as described in Section 3.1.2. The second set included 5 weekly sampling occasions from 9 March to 6 April. The data were treated as described in Section 3.1.2. The transformations and/or adjustments for each analysis of each plasma variable are summarized below:

Plasma variable	Mid pregnancy	Late pregnancy
3-OHB	Adjust N,D	$Translog_e$, adjust N,D
NEFA	-	-
Glucose	Adjust D	
Urea	Adjust N,D	

A similar analysis of variance was conducted on the ruminal fluid concentration variables, except that age, bearing type and time to parturition were not included as treatment factors in the analysis.

RESULTS (Section 3.2.3)

Estimates of herbage mass and *in vitro* OMD of harvested A/F material for each of the four plots are listed in Table 3.25.

Table 3.25 Herbage mass and OMD of A/F grassland at the start of the experiment

Plot	Treatment	Herbage mass (kg DM/ha)	OMD
1	A	2041	0.42
2	C	1592	0.39
3	B	1482	0.42
4	D	934	0.33

There are no error values owing to the method of bulking the samples for separation of the A/F component. Plot 4 had a lower herbage mass and *in vitro* OMD value for A/F grassland than the other plots.

Intake of supplement in mid pregnancy

The mean daily voluntary intake of supplement (VI) (derived from the weight of feedblock on the day of placement and on the day before the feedblocks were totally consumed), maximum daily intake within a week, and number of days in each week when a total of less than 5 kg feedblock remained for Treatments C and D is shown in Table 3.26.

Table 3.26 Daily intake of supplement as feedblock by ewes in mid pregnancy, when placed on A/F grassland or Calluna vegetation (Mean of 7 observations, see text for descriptions of VI and maximum intake)

Week beginning	Treatment C VI (g DM)	Maximum intake (g DM)	No. of days 5 kg of feedblock	Treatment D VI (g DM)	Maximum intake (g DM)	No. of days 5 kg of feedblock
	A/F grassland			Calluna vegetation		
11 January	106	133	0	0	0	0
18 January	184	307	0	134	249	0
26 January	181	257	1	154	324	0
1 February	226	332	2	177	324	1
	Calluna vegetation			A/F grassland		
8 February	166	415	0	176	232	0
15 February	211	332	1	231	291	2
22 February	292	299	3	254	415	3

For Treatment C the mean daily VIs of DM (± SE) by ewes were 186 (± 19.6) and 208 (± 28.6) g for the periods 18 January to 7 February and 8 February to 1 March respectively. For Treatment D the mean daily VIs of DM (± SE) were 157 (± 25.3) and 203 (± 16.8) g for the same periods of time. VIs for the week 11 to 18 January are excluded from these means because feedblock weights were not taken daily, and ewes on Treatment D, grazing mainly on areas of A/F, did not discover the feedblocks placed on the Calluna vegetation. They were driven up to the feedblock site when the second batch of feedblocks was positioned.

There was no effect of siting of feedblock on different vegetation types or of pattern of siting on mean daily VI of supplement, maximum intake or the number of days to exhaustion of feedblocks. VI and maximum intake of supplement increased over mid pregnancy and these changes are reflected in a reduction in the time taken to exhaust the feedblocks over mid pregnancy. Mean daily VI fell in the week after feedblock location was changed.

Intakes of supplement in late pregnancy

Over the period of late pregnancy the ewes consumed all the supplement offered. Any feedblock remaining when new feedblocks were allocated was not removed. The pattern of daily intakes of supplement by ewes in late pregnancy for each treatment is given in Fig. 3.10. The desired daily intake of supplement and the actual mean daily intake of feedblock by ewes for each week of the late pregnancy period together with the coefficient of variation of daily group supplement intake for each week are listed in Table 3.27.

Table 3.27 Mean daily DM intake of feedblock by ewes (DMI) and coefficient of variation (CV) of daily group supplement intake in late pregnancy (means of 7 observations)

Week beginning	Desired supplement intake (g DM/day)		Treatment A	B	C	D
7 March	164	DMI	130	131	193	134
		CV(%)	52	100	55	85
14 March	213	DMI	191	202	217	178
		CV(%)	29	53	55	54
21 March	213	DMI	213	216	211	244
		CV(%)	28	78	77	57
28 March	271	DMI	318	266	268	251
		CV(%)	25	80	77	85
4 April	328	DMI	195	242	254	234
		CV(%)	42	20	12	37

Daily intakes of supplement on Treatments B, C and D were extremely variable. Intakes on the days following the allocation of feedblocks were consistently higher than the mean intake for the week, leading to low daily intakes just prior to allocation of

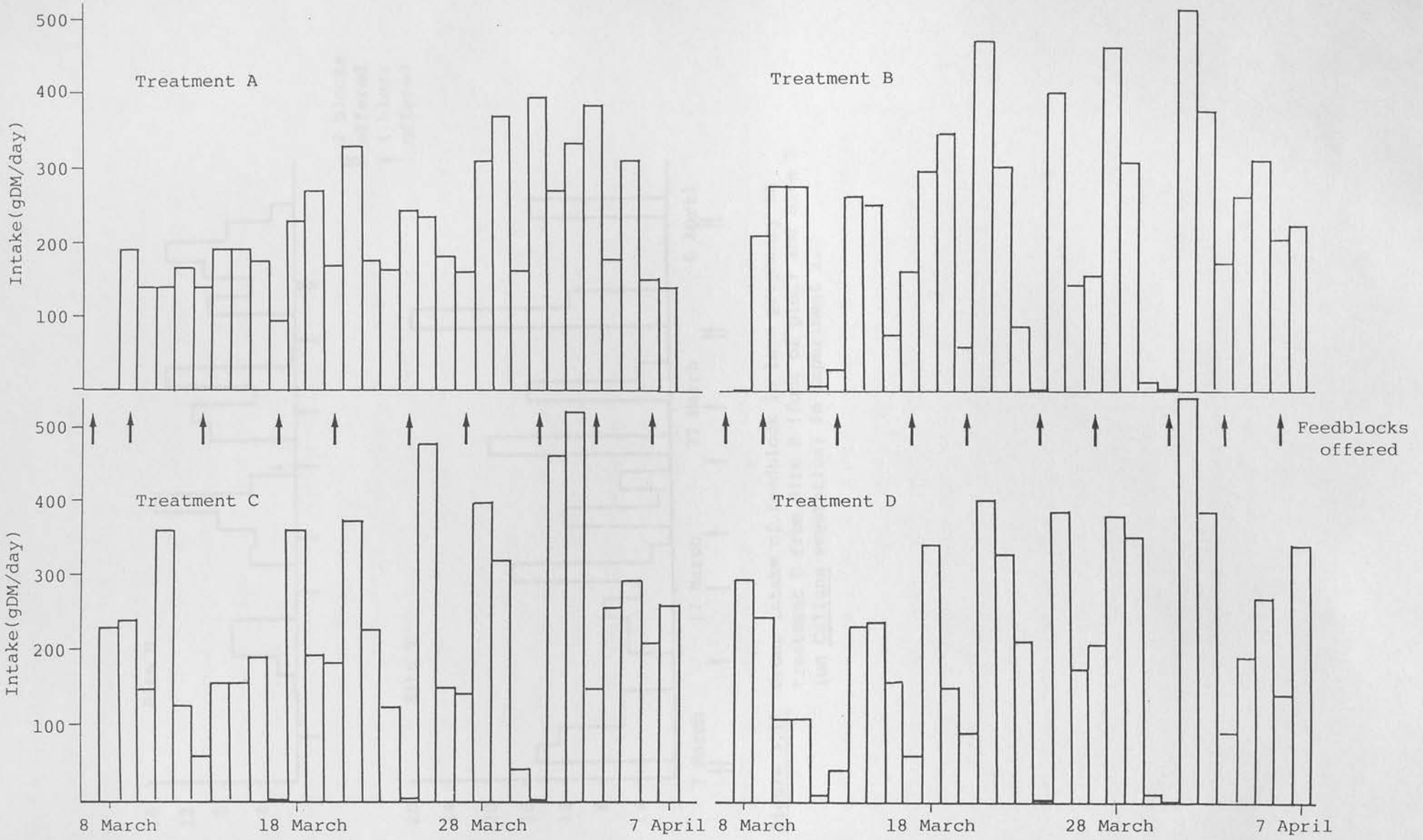


Figure 3.10 Pattern of daily feedblock intake in late pregnancy in Experiment 2

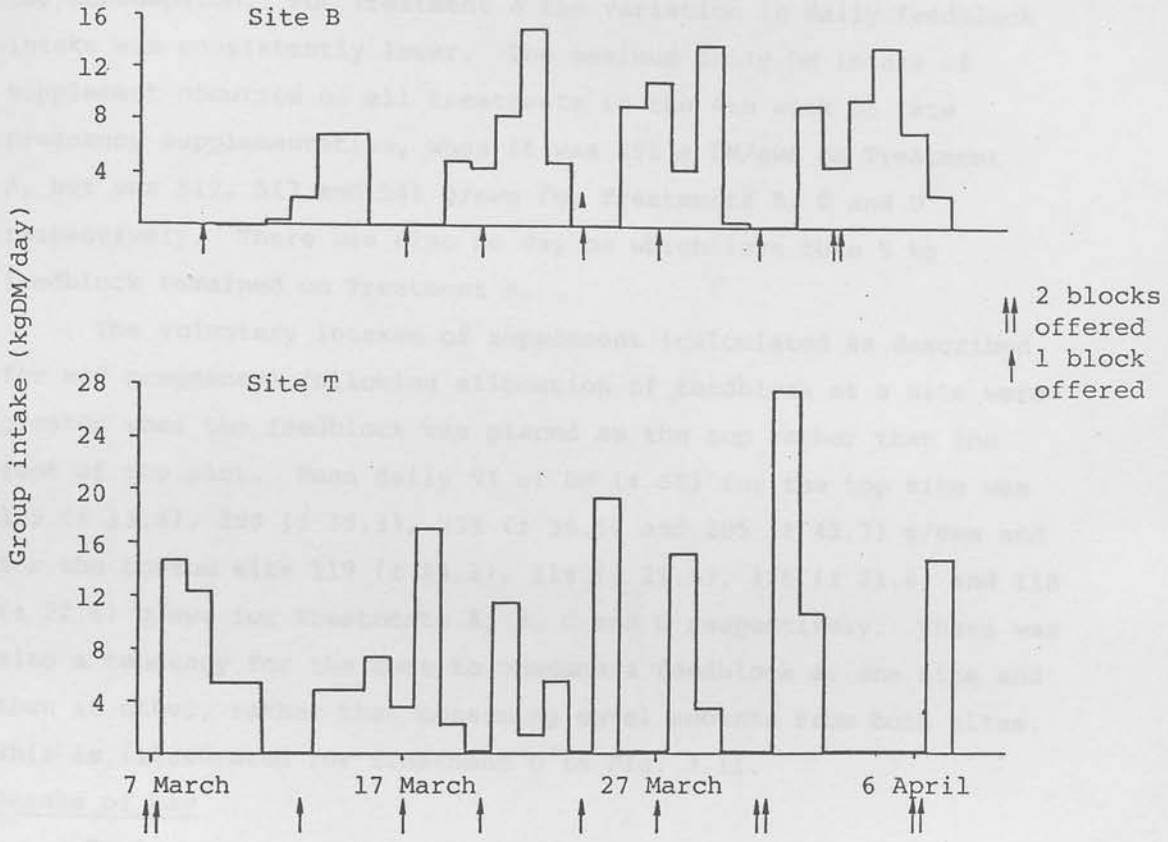


Figure 3.11 Group intake of feedblock in late pregnancy on treatment D from Site B (foot of plot) and Site T (on Calluna vegetation) in Experiment 2.

of further feedblocks.

For Treatments B, C and D there were 6, 5 and 6 days respectively when there was less than 5 kg of feedblock available for consumption. For Treatment A the variation in daily feedblock intake was consistently lower. The maximum daily DM intake of supplement occurred on all treatments in the 4th week of late pregnancy supplementation, when it was 396 g DM/ewe on Treatment A, but was 517, 517 and 541 g/ewe for Treatments B, C and D respectively. There was also no day on which less than 5 kg feedblock remained on Treatment A.

The voluntary intakes of supplement (calculated as described for mid pregnancy) following allocation of feedblock at a site were greater when the feedblock was placed at the top rather than the foot of the plot. Mean daily VI of DM (± SE) for the top site was 135 (± 13.4), 280 (± 36.3), 239 (± 36.5) and 205 (± 45.7) g/ewe and for the bottom site 119 (± 14.1), 118 (± 29.5), 125 (± 21.8) and 118 (± 22.6) g/ewe for Treatments A, B, C and D respectively. There was also a tendency for the ewes to consume a feedblock at one site and then at other, rather than consuming equal amounts from both sites. This is illustrated for Treatment D in Fig. 3.11.

Intake of hay

During snow cover in mid pregnancy 6.1 kg DM/Ewe was offered.

Ewe performance

The pattern of ewe liveweight over pregnancy for the treatments is illustrated in Figure 3.12. Mean liveweight (± SE) in November 1980 was 56.0 (± 0.36) kg. Small liveweight gains occurred in mid pregnancy, an unusual experience on this hirsel. Liveweight gains from the end of mid pregnancy to lambing were low. Table 3.28 gives the ewe liveweight changes over the production cycle in which the experiment was carried out.

The liveweight losses from the start of mating to the start of mid pregnancy were similar for all treatments. Over mid pregnancy supplemented Treatments C and D gained significantly more liveweight than the unsupplemented Treatment B ($p < 0.01$). The liveweight increase for the supplemented treatments was 2.0 kg compared with 0.5 kg for unsupplemented Treatment B. Ewes on Treatment A with the higher herbage allowance of A/F gained a

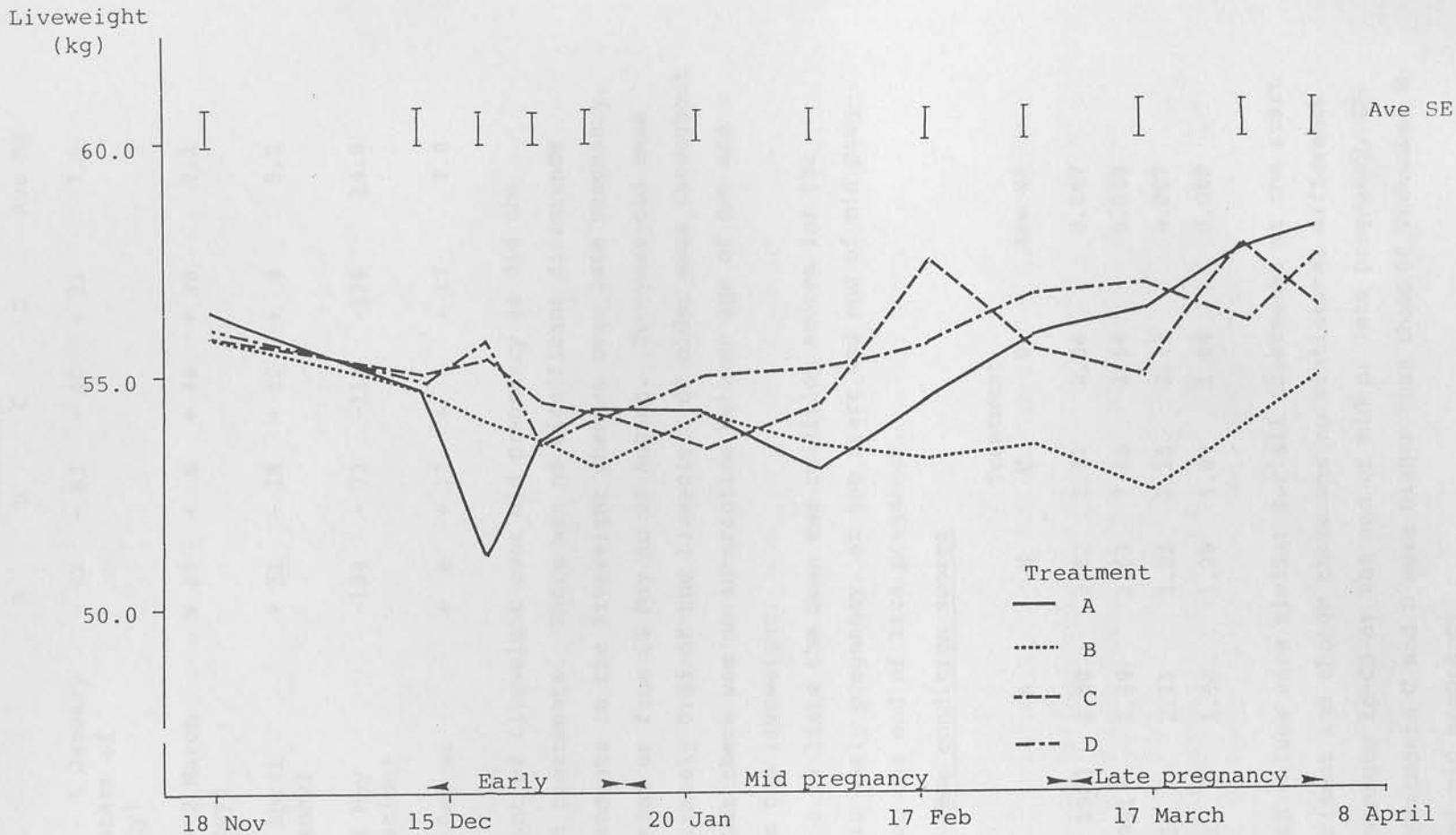


Figure 3.12 Pattern of ewe liveweight during pregnancy in Experiment 2

Table 3.28 Ewe liveweight changes (g/ewe/day) (adjusted means).

Period	Treatment A	B	C	D	Ave SE
18 November - 6 January (mating to start of mid pregnancy)	- 42	- 63	- 40	- 31	7.6
6 January - 2 March (mid pregnancy)	+ 25	+ 8	+ 46	+ 26	7.1
2 March - 8 April (late pregnancy)	+ 31	+ 18	+ 12	+ 9	5.5
8 April - 26 May (early lactation)	-124	- 73	-111	-136	14.8
26 May - 28 August	+ 6	+ 12	+ 6	+ 17	7.0

similar amount of liveweight over mid pregnancy as did the supplemented treatments. There was no significant difference between treatments in the liveweight changes over late pregnancy, early lactation or from 26 May to 28 August. Two-year-old ewes were approximately 0.83 of the liveweight of older ewes throughout pregnancy, but there was no interaction between age of ewe and treatment on the liveweight.

Table 3.29 lists the mean ewe condition scores for the treatments in early pregnancy, at the start and end of mid pregnancy, and at the end of late pregnancy.

Table 3.29 Ewe condition scores

Date	Treatment A	B	C	D	Ave SE
12 December 1980	2.80	2.82	2.77	2.86	0.067
6 January 1981	2.59	2.63	2.65	2.58	0.038
9 March 1981	2.11	2.02	2.15	2.13	0.097
8 April 1981	1.90	1.79	1.89	1.84	0.060

Mean CS values were similar for all treatments at the start of the experiment and though there was no statistical difference between treatments in CS at the end of mid or late pregnancy, CS values of Treatments C and D were higher than those of Treatment B at the end of mid pregnancy.

There was no difference in CS between age groups throughout pregnancy, nor was there an interaction between age of ewe and treatment on ewe CS.

Individual values for ewe performance data are listed in Appendix Table A 10.

The number of lambs at birth and on 26 May 1981, together with the numbers of ewes which were barren are listed for each treatment in Table 3.30.

Table 3.30 Ewe and lamb performance

	Treatment			
	A	B	C	D
No. of ewes pre-lambing	29	48	49	49
No. of barren ewes	6	5	12	4
No. of lambs born	33	64	56	62
No. of lambs born alive	31	60	51	60
No. of lambs alive at 26 May 1981	24	57	46	57

There was no significant difference between the treatments in the number of barren ewes or the number of lambs born per ewe. The overall proportion of barren ewes was 0.15, and the overall lambing rate was 1.19. Of the ewes classed as barren, 2, 6 and 4 ewes from each of Treatments A, C and D respectively either aborted or produced stillborn decomposing foetuses at term. Five lambs over all treatments died of starvation and exposure within the first week of life. The overall weaning rate was 1.01.

Lamb performance

The birthweights of single and twin lambs for each treatment are given in Table 3.31, together with the combined data for single and twin lambs. For single lambs there was a significant ($p < 0.05$) effect of sex of lamb and date of birth on birthweight. Male lambs were 0.4 kg heavier than female lambs, and lambs born in the first week were 0.4 kg lighter than lambs born in later weeks. For twin lambs there was a significant ($p < 0.05$) effect of age of ewe and date of birth on birthweight. Lambs born to 2-year old ewes were 0.9 kg lighter than those born to older ewes.

Table 3.31 Lamb birthweights (adjusted means)

	Treatment				
	A	B	C	D	Ave SE
Single lambs (kg)	4.03	3.75	3.92	3.91	0.121
Twin lambs (kg)	3.07	3.47	3.43	3.12	0.173
All lambs (kg)	3.79	3.50	3.65	3.65	0.088

There was no significant difference between treatments in the birthweights of single or twin lambs. There was, however, a significant ($p < 0.05$) treatment x age effect in the birthweights of twin lambs, and a similar but non-significant effect in the birthweights of single lambs. Twin lambs born to 2-year-old ewes weighed 4.21, 2.96, 2.45 and 2.61 kg (Ave SE 0.207) for Treatments A, C, B and D respectively. Single lambs weighed 4.08, 3.73, 3.33, and 4.13 kg (Ave SE 0.312) for corresponding treatments. Since the variances for single and twin lambs were shown to be homogeneous, the data for both lamb types were combined. Though the treatment x age interaction was non-significant, lambs born to 2-year-old ewes supplemented during mid pregnancy were 0.39 kg heavier than non-supplemented ewes, and 2-year-old ewes on Treatment A produced lambs 0.89 kg heavier than 2-year-old ewes on Treatment B. Differences between other age groups were small and not consistent.

Growth rate of lambs between birth and weaning are listed in Table 3.32. There was a significant ($p < 0.05$) effect of sex of lamb

Table 3.32 Lamb liveweight gains in lactation(g/day) (adjusted means).

	Treatment				
	A	B	C	D	Ave SE
Birth to 26 May	236	239	239	254	8.4
26 May to 28 August	164	161	161	158	6.1

and rearing type on liveweight gains from birth to 26 May such that, by this date, male lambs were 1.2 kg heavier than female lambs, and lambs reared as singles were 2.2 kg heavier than twin reared lambs. There was no significant difference between treatments in lamb liveweight gains, and the overall mean liveweight (± SE) on 26 May was 12.2 (± 0.19) kg.

From 26 May to 28 August, only rearing type explained a

significant ($p < 0.001$) amount of the variation in liveweight gains such that by weaning on 28 August, single reared lambs weighed 2.6 kg more than twin reared lambs. There was no effect of treatment on liveweight gains, on weaning, or on weaning weight. Overall weaning weight (± SE) was 27.4 (± 0.30) kg.

Individual values for lamb performance data are listed in Appendix Table A 11.

Intake of supplements by individual ewes on Treatments C and D in mid pregnancy

The DM intakes of supplement for each ewe are listed in Appendix Table A 12. The mean DM intake of supplement by the 10 ewes and the coefficient of variation in DM intake for each treatment for each period is given in Table 3.33, together with estimates of mean daily DM intake based on daily group intakes on the same days and on the 2 days prior to the start of faecal collection. In 3 out of the 4 comparisons, daily intakes of supplement for the sub group of 10 ewes were lower than those of the whole treatment group. Supplement intakes were similar when the feedblocks were placed on A/F grassland or heather vegetation. Coefficients of variation of supplement DM intake ranged from 31 to 61%, and were similar when feedblocks were placed on the different vegetation types.

For the 10 and 7 animals, samples on both occasions from Treatments C and D respectively, there was no significant rank correlation for intake of supplement on the two occasions (r_s = 0.33 and 0.48 respectively).

Table 3.33 Daily DM intake of supplement(DMI) and coefficient of variation (CV) on DMI by ewes

Date of sampling		Treatment C	Treatment D
28 January to 1 February	DMI (g)	131	201
	CV(%)	61	54
	* group DMI (g)	181	155
27 February to 3 March	DMI (g)	137	177
	CV (%)	50	31
	§ group DMI (g)	206	236

* Intakes from 26 to 31 January
§ Intakes from 25 February to 2 March

In vitro OMD of A/F in the diet: Treatments A and B

Mean adjusted values of OMD of extrusa samples for each treatment for each sampling occasion are shown in Fig. 3.13. There was a decline in OMD over the mid pregnancy period which was more marked on Treatment B. However, there was no statistical difference between Treatments A and B until 16 March when Treatment A was 0.062 units higher ($p < 0.001$) than Treatment B. Treatment A remained higher than Treatment B over the late pregnancy period and was 0.106 units higher ($p < 0.001$) on 6 April. Values of OMD remained high throughout the period from January to April.

Ruminal fluid concentrations: early and mid pregnancy

Mean NH_3, total VFA concentrations and the proportions of acetic, propionic and butyric acid in ruminal fluid are given in Table 3.34. Weekly values are given in Appendix Table A 12 for each sampling period for each treatment (see Section 3.2.2) Comparing non-supplemented Treatments A and B, there was no difference between the two treatments in ruminal NH_3 concentration in period 1. There was a significant ($p < 0.01$) fall in NH_3 concentration between periods 1 and 2 on both treatments, and although NH_3 concentration rose again in period 3 for Treatment A, it remained low for Treatment B. The changes in ruminal NH_3 concentration over mid pregnancy for Treatments A and B are illustrated in Fig. 3.14. Comparing unsupplemented Treatment B with supplemented Treatments C and D, when feedblocks were placed on A/F grassland (periods 2 and 3 for Treatments C and D respectively), there was no difference in ruminal NH_3 concentration. When feedblocks were placed on heather, however, ruminal NH_3 concentrations were lower for supplemented ewes than those not offered supplement. This difference was significant ($p < 0.05$) for period 3 when Treatments C and B are compared. When comparisons are made within Treatments C and D, the mean NH_3 concentration was higher when feedblocks were placed on A/F grassland than when placed on heather.

For period 1 and periods 2 and 3, when supplements were given, the mean ruminal VFA concentrations were significantly ($0 < 0.001$) higher for Treatments C and D than for Treatment B. There was a significant ($p < 0.01$) interaction between treatment and period for

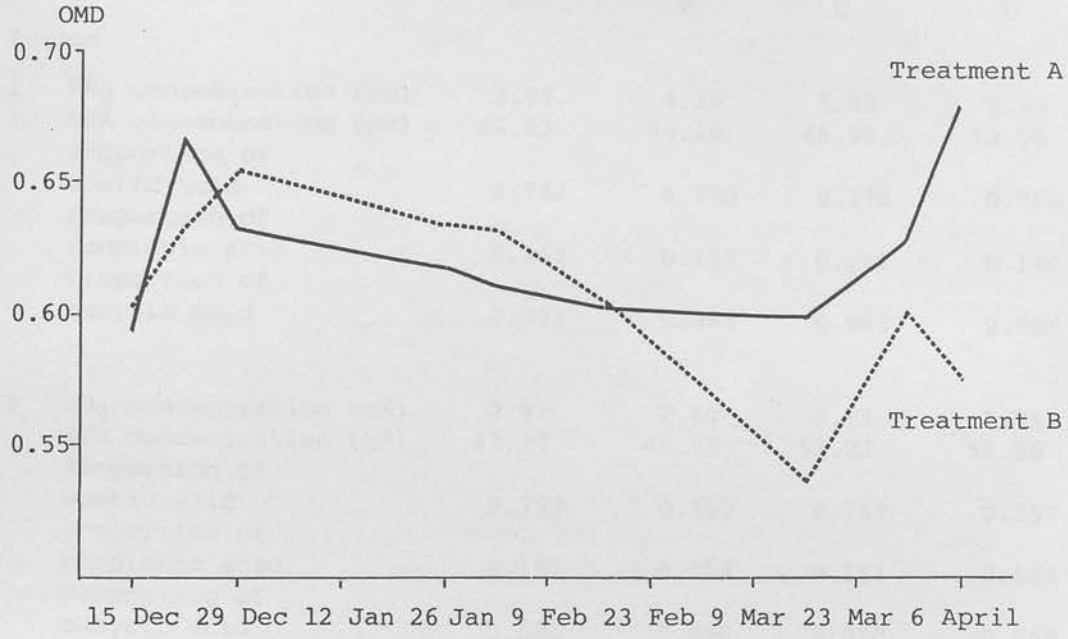


Figure 3.13 The in vitro OMD of œsophageal extrusa samples collected during pregnancy in Experiment 2. Ave SE for comparing treatments is 0.015.

Table 3.34 Concentration of NH_3 and total VFA, and proportions of acetic, propionic and butyric acids in ruminal fluid, in early and mid pregnancy (means of 24 observations in periods 1 and 3, and of 32 observations in Period 2).

		Treatment			
		A	B	C	D
Period					
1	NH_3 concentration (mM)	3.79	4.19	3.08	2.79
	VFA concentration (mM)	42.83	44.16	48.58	52.05
	Proportion of acetic acid	0.742	0.750	0.770	0.769
	Proportion of propionic acid	0.167	0.156	0.147	0.148
	Proportion of butyric acid	0.091	0.095	0.083	0.084
2	NH_3 concentration (mM)	2.99	2.80	3.14	2.25
	VFA concentration (mM)	45.27	46.90	53.03	50.96
	Proportion of acetic acid	0.767	0.750	0.749	0.757
	Proportion of propionic acid	0.152	0.154	0.161	0.144
	Proportion of butyric acid	0.081	0.096	0.090	0.099
3	NH_3 concentration (mM)	3.56	2.83	1.78	2.89
	VFA concentration (mM)	43.28	41.13	53.35	48.20
	Proportion of acetic acid	0.755	0.750	0.741	0.726
	Proportion of propionic acid	0.155	0.161	0.163	0.159
	Proportion of butyric acid	0.090	0.089	0.096	0.114

SED for comparing periods within treatments = V

SED for comparing different treatments and/or periods = HI

	V	HI
NH_3	0.377	0.432
VFA	3.081	3.199
Prop. acetic acid	0.0099	0.0091
Prop. propionic acid	0.0088	0.0077
Prop. butyric acid	0.0054	0.0050

the proportions of acetic, butyric and propionic acids. This reflected the feeding of supplements in periods 2 and 3 on Treatments C and D where the proportions of acetic acid declined and those of propionic and butyric acids increased.

Ruminal fluid concentrations in late pregnancy

Table 3.35 gives the mean concentrations of ruminal NH_3, total VFA and proportion of acetic, propionic and butyric acids over all sampling occasions in late pregnancy. Values for each sampling occasion are given in Appendix Table A 14.

Table 3.35 Mean concentration over 5 sampling occasions (9 March to 6 April) of ruminal NH_3 and total VFA concentrations, and the proportion of acetic, propionic and butyric acids (means of 40 observations)

	Treatment				
	A	B	C	D	Ave SE
NH_3 concentration (mM)	4.7	3.8	3.0	3.6	0.43
Total VFA concentration (mM)	52.6	44.8	50.4	46.1	1.73
Proportion of acetic acid	0.727	0.734	0.728	0.732	0.0060
Proportion of propionic acid	0.164	0.160	0.169	0.159	0.0044
Proportion of butyric acid	0.109	0.107	0.104	0.110	0.0040

Weekly means of ruminal NH_3 concentration for Treatments A (high allowance A/F) and B (low allowance A/F) are illustrated in Fig. 3.14. There was an increase in ruminal NH_3 concentration towards the end of pregnancy. Mean values for all treatments for 9, 16, 22, 30 March and 6 April were 2.8, 3.6, 3.2, 4.7 and 4.5 (Ave SE 0.30) respectively. Comparing treatment means for all 5 sampling occasions in late pregnancy, ruminal NH_3 concentration was higher on Treatment A than B, C and D, though only the difference between Treatments A and C was statistically significant ($p<0.05$).

There was a significant ($p<0.001$) treatment x week interaction in ruminal NH_3, although none of the effects could be explained by differences between treatments in availability of feedblock or timing

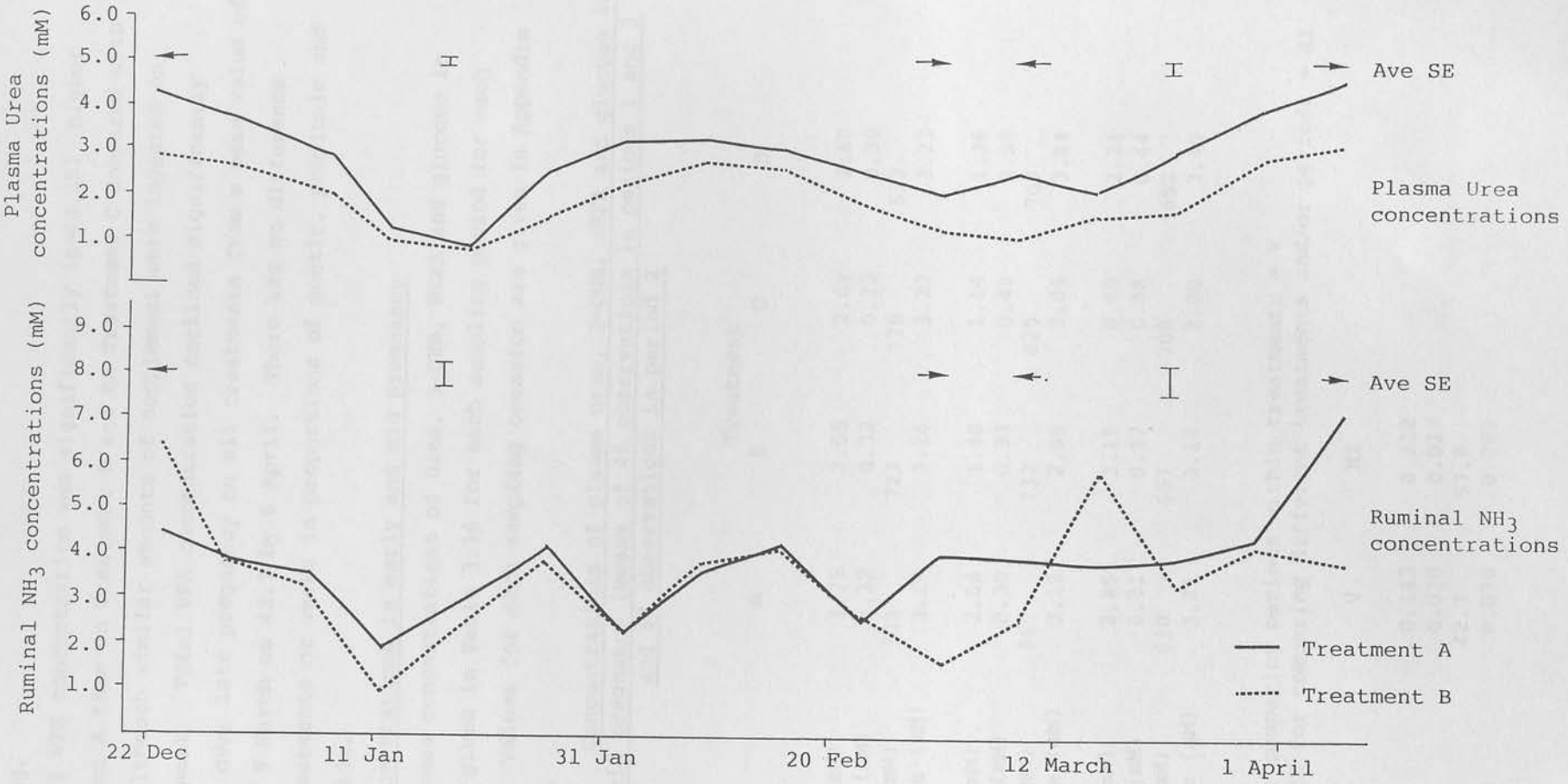


Figure 3.14 Concentrations of plasma urea and ruminal NH_3 during pregnancy for Treatments A and B in Experiment 2.

of sampling.

Total VFA concentration was significantly ($p < 0.05$) higher on Treatment A than on Treatment B and on Treatment C compared with B and D, although similar amounts of supplement were ingested on each treatment. Total VFA concentration declined significantly ($p < 0.001$) over late pregnancy on all treatments from a mean value of 56.8 mM on 9 March to 42.7 by 6 April. There was no difference between treatments or weeks in proportions of acetic, propionic and butyric acids.

Plasma concentrations in early and mid pregnancy

The mean concentrations of urea, 3-OHB, NEFA and glucose in plasma are given in Table 3.36 for each sampling period for each treatment. Values for each sampling occasion are given in Appendix Table A 15.

Table 3.36 Concentrations of plasma urea, 3-OHB, NEFA and glucose in early and mid pregnancy (means of 48 observations in periods 1 and 3 and 64 observations in period 2

		Treatment			
		A	B	C	D
Period					
1	Urea (mM)	3.78	2.55	2.09	2.60
	3-OHB (mM)	0.32	0.32	0.38	0.30
	NEFA (mM)	705	727	778	593
	Glucose (mM)	3.19	3.16	3.27	3.23
2	Urea (mM)	2.06	1.40	1.14	1.36
	3-OHB (mM)	0.30	0.33	0.45	0.39
	NEFA (mM)	762	732	825	707
	Glucose (mM)	3.12	2.99	3.05	3.04
3	Urea (mM)	2.85	2.15	0.98	2.24
	3-OHB (mM)	0.31	0.37	0.58	0.44
	NEFA (mM)	610	667	708	652
	Glucose (mM)	3.21	3.14	3.00	3.40

SED for comparing periods within treatments = V
Ave. SED for comparing different treatments and/or periods = HI

	V	HI
Urea	0.143	0.212
3-OHB	0.020	0.027
NEFA	42.7	57.8
Glucose	0.070	0.085

The changes in plasma urea concentration over mid pregnancy for the non-supplemented treatments are illustrated in Fig. 3.14. For each sampling period plasma urea concentrations were significantly higher ($p<0.001$) for Treatment A than B. For both Treatments A and B, the concentration of plasma urea was higher in period 1 than period 3, and higher in period 3 than in period 2 ($p<0.001$). Comparing supplemented Treatments C and D with Treatment B, the only difference in plasma urea concentration which was statistically significant ($p<0.001$) occurred in period 3 between Treatments B and C when feedblocks were placed on heather. When comparisons are made between Treatments C and D, plasma urea concentrations were significantly ($p<0.05$) higher when the feedblock was placed on A/F grassland than when placed on heather vegetation. On Treatment C plasma urea concentrations declined significantly ($p<0.001$) over periods 1, 2 and 3 when there were no feedblocks available, feedblocks on A/F grassland and feedblocks on heather vegetation respectively. On Treatment D, plasma urea concentrations fell ($p<0.001$) when feedblocks were supplied on Calluna vegetation in period 2, but rose again in period 3 when the feedblocks were moved to A/F glassland ($p<0.001$).

The concentration of 3-OHB rose between periods 1 and 2 for Treatments C and D and between periods 2 and 3 for Treatments B, C and D ($p<0.001$). There was no difference between Treatments A and B except in period 3 where plasma concentration of 3-OHB was higher for Treatment B ($p<0.001$). There was no effect of block placement on 3-OHB concentration, but supplemented Treatments C and D had higher concentrations of 3-OHB than Treatment B for the two periods when supplement was offered.

There were no significant differences between means in plasma NEFA concentrations. There were significant differences between periods for each treatment ($p<0.001$) and between treatments within each period ($p<0.001$) in the concentration of plasma glucose. However, the magnitude of the differences was small and no pattern could be detected.

Plasma concentrations in late pregnancy

Table 3.37 gives the adjusted mean concentrations of plasma 3-OHB, NEFA, glucose and urea for each treatment and each sampling occasion in late pregnancy. Values for each sampling date are given

in Appendix Table A 16. There was no significant difference between treatments in 3-OHB, NEFA or glucose concentration. Plasma 3-OHB and NEFA concentrations tended to rise over late pregnancy particularly for Treatments B, C and D. Bearing type and time to parturition affected plasma NEFA and 3-OHB concentration in a similar way to that described in Experiment 1 (Section 3.1.3)

Table 3.37 Adjusted mean concentration of plasma urea, 3-OHB, NEFA and glucose in late pregnancy for treatments (means of 80 observations) and sampling dates (means of 64 observations)

	Treatment				
	A	B	C	D	Ave SE
Concentrations of					
Urea (mM)	3.20	2.10	2.00	1.74	0.185
3-OHB (mM)	0.530	0.590	0.693	0.565	1.22*
NEFA (mM)	750	917	954	868	57.4
Glucose (mM)	3.27	3.08	3.25	3.22	0.069

	Sampling date					
	9 March	16 March	24 March	30 March	6 April	Ave SE
Concentrations of						
Urea (mM)	1.35	1.60	2.00	2.82	3.51	0.100
3-OHB (mM)	0.39	0.56	0.57	0.63	0.79	1.08*
NEFA (mM)	602	715	1087	786	1171	36.4
Glucose (mM)	2.97	3.05	3.28	3.02	3.26	0.049

* Two means are different ($p < 0.05$) if $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is > than the stated value.

Fig. 3.14 illustrated the change in concentration of plasma urea in late pregnancy for Treatments A and B, both of which were unsupplemented in mid pregnancy. Treatment A had consistently higher plasma urea concentrations than all three treatments where A/F covered 0.20 of the plot, and the overall mean for Treatment A was 1.6 that of Treatments B, C and D ($p < 0.001$). Plasma urea concentrations increased as pregnancy proceeded.

DISCUSSION (Section 3.2.4)

Comparison with Experiment 1

Comparing the overall performance of the ewes in Experiment 2 with that observed in Experiment 1, the lambing and weaning rates and the incidence of barren ewes were very similar. The pattern of change in CS during pregnancy was similar, though the magnitude of the loss in mid pregnancy from 2.62 to 2.10 was 0.22 units less for Experiment 2 than Experiment 1, and 0.06 greater in late pregnancy. The pattern of ewe liveweight change, however, was different between the two experiments. The ewes on Experiment 2 gained smaller amounts of liveweight during mid pregnancy (24 g/day) and late pregnancy (16 g/day) compared with larger liveweight losses in mid pregnancy (72 g/day) and liveweight gains in late pregnancy (42 g/day) in Experiment 1.

The herbage mass of A/F material in mid December 1981, at the start of Experiment 2 was similar to that observed in January 1980 in Experiment 1, but the in vitro OMD values of harvested material were generally 5 units higher in Experiment 2, except for plot 4 which had the lowest herbage mass and OMD values at the start of both Experiments 1 and 2. This has been attributed to higher bracken cover on the A/F areas (see Section 3.1.4). Using values of OMD for the dead and green components of the A/F pasture of 0.35 and 0.67 estimated by Eadie and Black (1968), it was estimated that the proportion of green material in the sward in Experiment 2 (0.16) was considerably greater than that on Experiment 1 (0.03). The oesophageal fistulated sheep selected material of high in vitro OMD value throughout the mid pregnancy period. The animals tended to graze the A/F areas near the foot of each plot, where the sward was denser than on the bracken-dominated areas higher up. There is no evidence from Experiment 1, where the sites of grazing were recorded, that material of higher in vitro OMD value was selected in any given area of plots 1 and 3, and it is likely that the ewes would preferentially graze areas so that the in vitro OMD values of the diet selected were uniformly high. However, the results from the first sampling occasion for Treatments A and B in Experiment 2, where the fistulates grazed on the bracken-dominated areas, gave

values of *in vitro* OMD 3 - 5 units lower than those observed on the 2 subsequent occasions. Furthermore, ruminal and plasma concentrations of the variables measured were similar in Experiments 1 and 2 throughout most of pregnancy, implying no large differences in overall diet quality between the two experiments. The conclusions drawn are that the OMD values of the diet selected from A/F in Experiment 2 were higher than for Experiment 1, although not necessarily as high as the *in vitro* OMD values of extrusa samples imply, and this reflects the higher proportion of green material, and that heather, as the other major component of the diet, has an important influence on rumen and plasma parameters.

The differences between the two experiments in the pattern of ewe liveweight change is considered, in part, to reflect the different managements at the start of the experiments and their effects on changes in gut-fill. Russel *et al* (1968) reported a reduction in gut-fill from 11.0 kg in November to 7.5 kg in March for Scottish Blackface ewes (liveweight 47 kg in November) grazing hill pastures containing 0.50 heather. The magnitude of this change must depend to some extent upon changes in the amount and quality of pasture available. In Experiment 2 when the ewes returned to the hill grazing in mid December it is argued that there was a comparatively high herbage supply and quality (for example, plasma urea concentrations on the first sampling occasion were 4.0 mM compared with 2.5 mM in Experiment 1) and this reduced liveweight losses associated with changes in gut-fill. In Experiment 1 gut-fill changes were considered to be greater. The smaller gut-fill changes together with the smaller losses in material tissues observed in this experiment provide an explanation for the differences in pattern of liveweight change between the two experiments. The weather was similar in both years (see Appendix Table A 27), with similar amounts of hay being offered during periods of snow cover, making it unlikely that pasture availability could have had an important effect.

Birthweights of twin lambs were 0.27 kg heavier over all treatments in Experiment 2 than in Experiment 1, perhaps reflecting the 20% increase in late pregnancy supplementation. Birthweights of single lambs were similar to those of Experiment 1, and 3-OHB

concentrations were low in late pregnancy and similar to those observed in Experiment 1.

Allowance of A/F

There was a 4.6 fold difference in the allowance of A/F between Treatments A and B. There was no significant difference in ewe liveweight change over mid or late pregnancy. However, if the pattern of ewe liveweight change over the whole of pregnancy is considered, ewes on the higher allowance treatment had higher liveweights from late February onwards (see Fig. 3.12). Higher lamb birthweights with the higher allowance of A/F were observed in the 2-year-old ewes. Differences in the other age groups were small and inconsistent even for twin lambs. It has been argued in Section 2 that nutrition in pregnancy is likely to be of greater importance to 2-year-old ewes and those bearing twins. The differences in response between young and older ewes is somewhat surprising as there was no treatment x age interaction in the liveweight changes or condition scores of the ewes. There was no difference in the *in vitro* OMD of extrusa samples or in ruminal NH_3 or VFA concentrations during early and mid pregnancy. However, plasma urea concentrations were consistently higher for ewes on the high allowance of A/F though the magnitude of difference was small. In late pregnancy, *in vitro* OMD values of extrusa samples, ruminal VFA concentrations and plasma urea concentrations were higher from mid March onwards on the higher allowance treatment, but there was no significant difference in plasma concentrations of 3-OHB, NEFA or glucose. This latter observation is surprising since although the ewes on both treatments were receiving the same amounts of supplementary feeding during late pregnancy, the evidence from other observations would suggest a higher energy intake from pasture on the high allowance in late pregnancy. However, in Experiment 1 ewes had to be offered 14% more supplementary feeding to maintain 3-OHB below 0.9 mM on the high allowance of A/F despite evidence of an advantage in the quality of A/F in late pregnancy.

The conclusions that can be drawn from Experiments 1 and 2 are that on heather dominant hills with 0.20 to 0.40 of the area as A/F grassland where the herbage masses of A/F are 1500 to 2000 kg DM/ha and proportions of green material are less than 0.15, and at stocking rates of 1 to 2 ewes/ha, differences in mid pregnancy nutrition are small and unlikely to lead to differences in ewe and lamb performance,

except for 2-year-old ewes, when ewe body condition is high at the start of winter.

Supplementary feeding in mid pregnancy

Supplementary feeding during mid pregnancy increased liveweight gain and reduced the loss in condition score compared with unsupplemented ewes. The birthweight of lambs from 2-year-old ewes was 0.39 kg heavier for ewes supplemented in mid pregnancy, but differences in lamb birthweight for older ewes were small. The lack of an effect of supplementation in mid pregnancy on lamb performance compared with Experiment 1 is considered to be due to a higher overall plane of nutrition received by ewes on all treatments in mid pregnancy. Arguments have already been put forward explaining why there was no fall in liveweight during mid pregnancy. Changes did take place in CS in mid pregnancy between supplemented and unsupplemented treatments, and, although the differences were similar in this experiment those in Experiment 1, the overall magnitude of the reduction in CS was less in Experiment 2 than in Experiment 1.

In spite of increasing the supplementary N intake from 4.4 to 6.1 g/day, no difference between the ruminal NH_3 and plasma urea concentrations of supplemented and unsupplemented ewes was seen. Indeed, the levels of these metabolites was more influenced by the position of feedblock placement and presumably the nature of the vegetation ingested. Lower ruminal NH_3 and plasma urea concentrations were found when feedblocks were placed on heather than A/F vegetation. The low ruminal NH_3 concentrations found even when ewes were sampled no more than an hour after ingesting feedblock suggests that an alternative form of N supplement to urea such as a vegetable protein source could be more effective.

Intake of supplement

Voluntary intakes of feedblock increased with time during mid pregnancy and were higher than the desired level by weeks 2 and 4 of the supplementation period for Treatments C and D respectively. Ewes unsupplemented in mid pregnancy on Treatment B very quickly reached the desired levels of intake in late pregnancy, but the voluntary intakes by ewes on the high allowance of A/F treatment were consistently lower with feedblock remaining on 17, 24 and 28 March, reflecting perhaps a greater supply of nutrients from grazed herbage. The increase in consumption of self help supplements with

time is well documented, though why this should be so is not always clear.

In this series of experiments increasing nutritional demands with advancing pregnancy could be one reason, although Ducker and Fraser (1975), Kendall (1977) and Ducker et al (1981) found no evidence of sheep regulating intake according to their nutritional requirements. Furthermore, Kendall (1977) and Kendall et al (1983) reported increases in intake of feedblocks over time by small groups of housed barren ewes receiving hay ad libitum. Increase in group intakes results from an increase in the proportion of animals consuming supplement as well as increases in the intakes of those animals already eating the supplement. A wide range in the time taken for animals to reach maximum intakes of supplements has been reported. Tulloh, Watson and Burnett (1963) reported maximum intakes of 'blocks' (wheat based) including 0.30 E C feed and 0.20 - 0.30 salt after 8 weeks. The sheep, wethers grazing arid pastures, were only permitted to lick the feedblock. Creswell, Gill and Fraser (1968) noted increases in intake of 'Rumevite' type feedblocks by Herdwick wethers (18.7 kg at the start of the trial) over 21 weeks. Again the animals were only permitted to lick the supplement. Pearce and Raven (1973) noted an increase in feedblock consumption by cattle, but this was affected by the urea content, increasing the amounts of nitrogen supplied by urea increasing the time to reach maximum intakes. In most of the cases reported, intakes reached levels which were higher than was biologically necessary or economically desirable.

Controlling intakes by limiting the frequency of supply resulted in the highly variable between-day pattern of intakes recorded in this experiment. In late pregnancy this variability in the daily amount of feedblock when superimposed upon considerable between-ewe variability in intake appeared to have undesirable consequences. Three ewes suffered from pregnancy toxaemia, and 12 ewes were known to have aborted, although toxoplasmosis was implicated in at least 2 of these cases. Hart (1973) reported a high incidence of pregnancy toxaemia in hill ewes with access to liquid feeders, though not with feedblocks. Some means of identifying non-eaters of feedblock in late pregnancy would be desirable.

There was little effect of siting of feedblock on consumption in this experiment when feedblocks were placed at one site only. However, the ewes showed a preference for feedblocks offered on heather vegetation to those offered simultaneously on A/F grassland at the foot of the plot. In late pregnancy the ewes grazed less frequently near the lower feedblock site, whilst the feedblocks on heather vegetation were within the daily movement of the sheep over the plots.

Supplement intakes and associated variability in group intake were lower for Treatment A than Treatments B, C and D in late pregnancy. Ducker and Kendall (1977) reported a reduction in feedblock intakes with increasing pasture availability. Ewes on Treatment A had 3.3 x the area of A/F per ewe, and the evidence from blood rumen and OMD parameters suggests that Treatment A had access to vegetation of higher quality than the other treatments in late pregnancy.

Coefficients of variation for individual ewe intake of feedblock on Treatments C and D were high; of a similar order to those observed in Experiment 1. Mean individual intake of feedblock by the ewes on which measurements of intake were made were 0.86 that of the group intake measured by daily weighing of feedblock.

In Experiment 1, high variability in Cr content of feedblock was cited as a possible reason why feedblock intakes of individual ewes measured by Cr_2O_3 dilution were lower than group intakes. The opportunity was taken in this experiment of examining variation between feedblocks and within feedblocks. The results are given in Appendix Table A 28. Between-feedblock variability (coefficients of variation 5 - 15%) was found to be similar or higher than within-feedblock variability (coefficients of variation 2 - 10%). Care was taken in this experiment to ensure that all feedblocks on offer prior to and during each faecal collection period were sampled.

Summary

A 4.6 fold difference in the initial allowance of A/F had no effect on ewe performance in mid pregnancy, but increased birthweight

of lambs born to 2-year-old ewes.

Supplementary feeding during mid pregnancy increased liveweight gain and reduced the loss in condition score compared with unsupplemented treatments. An increase in birthweight was again only observed in 2-year-old ewes. The lack of effect of the supplement is thought to be due to a higher overall plane of nutrition on all treatments in mid pregnancy.

EXPERIMENT 3: intake characteristics of feedblocks differing in intake potential.

INTRODUCTION (Section 3.3.1)

Two feedblocks differing in intake potential were offered to ewes during Experiment 2: a 'low intake' feedblock during mid pregnancy, designed to supply small amounts of nitrogen and energy, and a 'high intake' feedblock in late pregnancy to supply a greater proportion of the ewes' nutrient demands. Voluntary intakes rose over mid and late pregnancy, resulting in highly variable intakes when the animals were restricted by frequency of feedblock replenishment. The higher voluntary intakes observed in late pregnancy could have been due to the sequence of block feeding, or to increased nutrient requirements coupled with low availability of herbage (particularly on Treatments B, C and D), rather than factors intrinsic to the feedblocks.

It is claimed that differences in intake between feedblock types can be achieved by altering their composition such that palatability and hardness are changed. Kendall et al (1980) reported higher intakes of 'high' compared with 'low intake' feedblocks similar to those used in Experiment 2. However, this might have been because of the feeding sequence (the 'low intake' feedblock was followed by the 'high intake' feedblock), since intakes of feedblock were found to increase over the feeding period in Experiments 1 and 2, and in the experiment of Creswell et al (1968). However, the intakes of both feedblocks were low, being less than 105 g DM/ewe/day. An experiment was therefore set up to describe the intake characteristics of 2 feedblocks with 'high' and 'low' intake potential when compared over the same period of time, and offered ad libitum with the objective of establishing the effects of intrinsic feedblock characteristics on supplement intake.

MATERIALS AND METHODS (Section 3.3.2)

Treatments and feeds

The pattern of intake of two feedblocks differing in intake potential by two groups of ewes (A and B) was compared in a double reversal design with 4 periods. The 'low' (L) and 'high' (H)

intake feedblocks were the same as those offered in mid and late pregnancy in Experiment 2, and their composition is given in Table 3.24. The sequence of distribution of the two feedblock types and the duration of each feeding period is given in Table 3.37.

Table 3.37 Allocation of feedblocks to ewes in groups A and B.

Period	Date	Group A	Group B
1	30 December 1980 to 10 January 1981	H	L
2	10 January 1981 to 26 January 1981	L	H
3	27 January 1981 to 9 February 1981	H	L
4	10 February 1981 to 22 February 1981	L	H

One feedblock was placed near the centre of each plot and was replaced with a new feedblock when less than the previous day's intake remained. Cr_2O_3 was incorporated into feedblocks L and H at approximately 8.5 and 4.5 g/kg DM respectively.

Animals and management

The experiment was conducted with 30 Scottish Blackface ewes grazing two adjacent plots of heather dominant rough grazings with areas of 5.5 and 4.5 ha. The age distribution of the ewes is shown in Table 3.38.

Table 3.38 Age distribution of ewes at October 1980

Age	No. of ewes
2	8
3	5
4	6
5	2
6/7	9

The 2 - 5-year-old ewes were drawn randomly from the flock from which the ewes used in Experiment 2 were drawn. Ewes aged 6 years and older were from a flock of draft ewes. All ewes had a full complement of teeth at the start of the experiment and had had previous experience of feedblocks. The ewes were joined with rams fitted with marker crayons on 18 November 1980, on improved pasture. On 30 December 1980, the ewes were allocated randomly to form two groups, A and B, of 15 ewes balanced for age, liveweight

and mating date, and which grazed the 5.5 and 4.5 ha plots respectively until 22 February 1981. Decision rules covering periods of inclement weather were the same as those described in Section 3.1.2. From 23 February, the ewes were run as a single group over both areas until they were placed on improved pasture for lambing. They were offered supplementary feeding (Ewemax cubes, SAI Ltd.) increasing from 170 g DM/ewe on 23 February to 340 g DM/ewe prior to lambing.

Measurements

Ewe and lamb performance The ewes were weighed and condition scored as described in Section 3.1.2 at approximately 2-week intervals. Lambs were ear-tagged within 24 h of birth and records taken as described in Section 3.1.2.

Group intake of feedblock Feedblocks were weighed daily to the nearest 0.5 kg.

Intake of supplements by individual ewes Intake of supplements was measured as described in Section 3.1.2. Total faecal output was measured on 10 ewes (excluding 2-year-old ewes) for the last 5 days of each period. The same ewes were sampled on each occasion.

Plasma metabolite concentrations Measurements of concentrations of NEFA and urea in plasma were made. Blood samples were taken at 0900 h from the ewes on which measurements of faecal output were made on one day in the last 5 days of each period. The samples were processed and analysed as described in Section 3.1.2.

Statistical analyses

Analysis of variance was carried out on feedblock intake data using Edex (Hunter et al 1979). Variations associated with group of ewes, period and feedblock type were removed as treatment factors. Rank correlations were calculated as described in Section 3.1.2.

RESULTS (Section 3.3.3)

Ewe and lamb performance

The initial mean liveweight and condition score of the ewes on 7 January 1981 was 57 kg and 2.7 respectively. The ewes lost only small amounts of liveweight (0.9 kg) and condition score (0.2) during

the experimental period to 24 February 1981. Lamb birthweights (± SE) for both groups were 3.8 (± 0.28) and 3.4 (± 0.13) for the 10 single and 15 pairs of twin lambs born alive respectively. There was no difference in performance between the groups.

Plasma metabolite concentrations

The plasma urea (range 1.6 - 3.2 mM) and NEFA (range 375 - 720 mM) concentrations were similar to those obtained in Experiment 2.

Group intake of feedblock

Voluntary intakes of feedblock for each plot expressed on an individual ewe basis are given in Table 3.39.

Table 3.39 Voluntary intake of DM (VI) and coefficient of variation (CV) between days of intake of feedblock DM by ewes.

	Period			
	1	2	3	4
Group A feedblock	H	L	H	L
VI (g DM/ewe/day)	228 (9)*	270 (15)	425 (14)	276 (12)
CV (%)	46	32	34	18
Group B feedblock	L	H	L	H
VI (g DM/ewe/day)	123 (10)	278 (16)	330 (14)	374 (12)
CV (%)	38	30	29	44

* No. of observations
Ave SE for intake means = 29.7

Intakes rose over the three final periods of the experiment regardless of feedblock type or group of ewes. Intake by Group A ewes in period 4 fell when the feedblock was changed from H to L. Mean VI values were 71 g DM/day higher ($p < 0.001$) for the H than the L feedblocks (330 as against 259 g DM/ewe/day respectively). Coefficients of variation between days were lower for feedblock L (29%) than H (39%).

Intake of supplements by individual animals

The intake of DM of supplement for each ewe is listed in Appendix Table A 17. The mean intake of supplement by the 10 ewes sampled and the coefficient of variation for each group for each collection period are given in Table 3.40, together with estimates

of daily group intake recorded during and on the two days prior to the start of the faecal collection period.

Table 3.40 Daily intake of DM (DMI) of feedblock by ewes and coefficient of variation (CV) of DMI of feedblock.

	Period			
	1	2	3	4
Group A feedblock	H	L	H	L
DMI (g/day)	256	264	442	323
CV (%)	51	32	32	39
Group DMI (g/day)	268	267	422	263
Group B feedblock	L	H	L	H
DMI (g/day)	95	240	279	318
CV (%)	74	50	21	25
Group DMI (g/day)	143	336	290	368

Mean intakes of supplement were similar to those obtained for group intakes with the same effects of period and feedblock on supplement intake. Coefficients of variation in the DMI of supplement by ewes were high in Period 1 (63%), declining to 41, 27 and 32% in Periods 2, 3 and 4 respectively. There was no difference between feedblocks H and L in coefficient of variation values.

For sheep on Plots A and B there were significant ($p<0.05$) multiple rank correlation coefficients (W) of 0.77 and 0.55 respectively for rankings of DM intake of supplement by individual ewes in each sampling period. Rankings for different sampling occasions were related as follows: for Group A between Periods 2 and 3, $r_s = 0.86$ ($p<0.01$), and between Periods 3 and 4, $r_s = 0.81$ ($p<0.01$). For periods 1 and 3, when ewes in group A received the L feedblock, the r_s value was 0.65 ($p<0.05$) and for Periods 2 and 4 when ewes in Group A received the H feedblock, the r_s value was 0.78 ($p<0.01$). For Group B between Periods 1 and 2 there was an r_s value of 0.90 ($p<0.001$) and for Periods 2 and 3 an r_s value of 0.62 ($p<0.05$).

DISCUSSION (Section 3.3.4)

Voluntary intakes of feedblock in this experiment were similar to those observed for the corresponding feedblocks in Experiment 2. Voluntary intakes in Experiment 2 during mid pregnancy (feedblock L) rose to 292 and 254 g DM/day for Treatments C and D respectively, compared with values of 276 - 330 g DM/day obtained in this experiment. During late pregnancy in Experiment 2, (feedblock H) supplement intake increased from 227 to 373 g DM/day for Treatments B, C and D, whilst intakes of 374 - 425 g DM/day were recorded in this experiment. The voluntary intake of feedblock H was greater than that of L under the comparable conditions of this experiment, although part of the reason for the difference was the low intakes of feedblock L in period 4 with Group A. Voluntary intakes of feedblock increased as pregnancy advanced, but it was also shown that there are differences in intake between feedblocks which are independent of this time trend. There are several possible reasons for the higher intakes of feedblock H. Feedblock L contained more urea which, in increasing concentrations, has been shown to reduce intakes (Pearce and Raven, 1973). Salt is often considered to be a means of controlling intakes, but the salt content of both feedblocks was similar, and unlikely to affect intake at the levels of inclusion used. Studies on the use of salt as a supplement intake regulator have been confined mainly to arid environments. Weir and Miller (1953) found that intakes of a cotton-seed meal mixture with 25% salt, though initially controlled at 115 g/day, rose over a 16 week period to 318 g/day. The ewes in the experiment were kept inside on a dry ration. Hentges (1967) concluded with steers that, although 16% salt limited intake of a ration, it was not a very efficient method of intake control, owing to the large variability in intake between animals. The proportion of E C feed used as a hardening agent (Kendall, 1977; Tulloh et al, 1963) was also similar in both feedblocks. No attempt was made to compare the hardness of the two feedblock types for although Stewart, Taylor and MacBean (1978) estimated comparative hardness of whey feedblocks from the penetration of a probe dropped from a standard height, hardness as such may have limited potential in controlling

intakes. Under field conditions feedblocks absorb moisture, the surface becomes soft, and the material is easily consumed. There were differences in other constituents of the feedblocks which resulted in differences in block texture and these may offer an explanation for the lower intakes of feedblock L found in this experiment.

Variation in supplement intake between days was high, despite the feedblocks being offered ad libitum. This was particularly so for feedblock H, and is in agreement with the findings of Kendall et al (1983). This implies that factors other than availability of feedblock are associated with between-day variation in supplement intake. The most likely factor is weather conditions, since Ducker and Fraser (1975) observed differences in feedblock intake associated with differences in snow cover and ambient temperatures. Snow cover reduces herbage availability, thus stimulating feedblock intake. Cold and dry weather will tend to keep the surface of the feedblock hard, whilst wet weather will soften it.

Coefficients of variation in individual ewe intakes were similar for both feedblocks, and they were of the same order as those observed in mid pregnancy for ewes in Experiment 2. Kendall et al (1983) suggested that, as supplement intake increased, coefficient of variation in intake between animals declined. This was the case in this experiment as pregnancy proceeded, and reflected a similar range in individual intakes throughout the period, being associated with an increasing mean intake of supplement. There were consistent rankings of ewes in supplement intake in this experiment and in Experiment 1. Such rankings were not observed in Experiment 2, possibly because there were several days of low availability of feedblock in some weeks, and it may be that some ewes were not always able to reach their maximum voluntary intakes.

This implies that competition for feedblock based on social hierarchy may not be an important source of between-animal variation in supplement intake, since low availability of feedblock would reinforce any social hierarchy and augment the rankings observed.

EXPERIMENT 4: to investigate the use of Ruthenium Phenanthroline complex (Ru-Phen) as a marker to measure faecal output by ewes when administered orally once daily.

INTRODUCTION (Section 3.4.1)

To obtain reliable estimates of supplement intake from faeces output, the concentration of the supplement marker in the faeces must be measured over periods of at least 4 - 5 days, owing to the high between-day variability in both these components, for example, as observed in Experiment 1. Total collection of faeces is not practicable on a large number of ewes under extensive conditions, and estimates of faecal output require to be determined by the quantitative administration of a second marker and determination of its concentration in faecal grab samples. Such a marker should be totally recovered in faeces, not interfere with digestion processes and be relatively easily measured along with the other marker. Under extensive conditions where it is only practicable to give the marker and collect faecal grab samples once daily it should also give unbiased estimates i.e without diurnal patterns of excretion.

Metal oxides and salts, although their recovery rates may be complete, show appreciable diurnal and daily variability in excretion when administered in a single daily dose (Elam, Putnam and Davis, 1959; Troelsen, 1965). The radioactive phenanthroline complex of the rare earth metal, ruthenium, (^{103}Ru-labelled (tris 1, 10 phenanthroline) ruthenium II chloride - ^{103}Ru-Phen), however, is strongly absorbed onto the particulate phase of digesta (Tan, Weston and Hogan, 1971) and has been extensively used as a dual-phase marker in conjunction with ^{51}Cr EDTA in digestion studies. It has little effect on rumen metabolism within certain concentration limits and has near complete recovery rates (MacRae, 1974; Faichney, 1975). Evans, MacRae and Wilson (1977) reported the use of inert Ru-Phen and its quantitative estimation by X-ray fluorescence spectrophotometry. Cr determinations can be made on the same sample, making the use of the inert Ru-Phen complex feasible for field experiments. However, reports of its use to

date have involved the continuous infusion of a solution of the complex. Since quantitative administration of a single daily liquid dose by mouth to sheep is difficult, the Ru-Phen complex was absorbed onto cellulose powder, before administration in gelatin capsules. An experiment was conducted to measure the effect of once daily dosing with cellulose powder with adhering Ru-Phen complex on the time to reach constant marker excretion, the daily and diurnal variability in faecal marker concentration and on the recovery of the marker in the faeces. To enable rapid analysis of results, radioactive ^{103}Ru-Phen was used.

There are numerous reports in the literature (Elam et al, 1959; Troelsen, 1965; MacRae and Armstrong, 1969), indicating large daily and diurnal fluctuations in excretion of Cr_2O_3 when administered once daily. Since ewes had been observed in Experiments 1 and 2 to consume several small meals of feedblock daily, this should reduce fluctuations in faecal marker concentration. The opportunity was taken to investigate the faecal excretion patterns of Cr when feedblock was offered in two meals daily at levels of intake similar to those found in Experiments 1, 2, and 3. Since the pattern of excretion of either marker may be influenced by the pattern of roughage intake, the roughage was fed in two meals to simulate the sunrise and sunset peaks of grazing activity seen in sheep at pasture (Hafez, 1962; Arnold and Dudzinski, 1978).

MATERIALS AND METHODS (Section 3.4.2)

Four non-pregnant, non-lactating Scottish Blackface ewes (aged 4 years, liveweight 50 kg) were housed in metabolism cages 2 days before the start of the 14 day experimental period. They were offered half their daily ration of 850 g DM poor quality hay and 164 g DM feedblock (Rumevite Extra Energy, Rumenco Ltd., Burton on Trent) at 0800 and 1600h. The feedblock was presented in small pieces. Any refusals were collected at 0800h.

Faeces were separated from urine and daily faecal output collected at 0900 h from days 1 to 12 and at 3-hourly intervals for 48 hours from 0900 h on days 13 and 14. The faeces from each collection was weighed, thoroughly mixed and a 10 g subsample

taken for estimation of DM and radioactive counting.

$^{103}Ru\ Cl_3$ was converted into 250 ml ^{103}Ru-Phen (630 n Ci) using the method described by Tan et al, 1971. Additional Ru-Phen carrier was added. Cellulose powder (25 g) was added, mixed with the solution and allowed to stand overnight. It was filtered and the cellulose powder with adhering complex was dried at 80°C for 24 h. The dried material was mixed and 0.48 g weighed into gelatin capsules. Each capsule was placed in a vial and its radioactivity determined in a liquid-scintillation counter (Autogamma 800, Packard Instrument Co., Illinois, USA) prior to each ewe being dosed with one capsule at 0900 h daily during the experiment. All counts were corrected for decay of radioactivity from day 1 of the experiment. Faecal samples from days 11 and 12 and from the 3-hourly samples from days 13 and 14 were also analysed for concentrations of Cr and Ru by X-ray fluorescence spectrometry using a similar technique to that described by Evans et al, 1977. Cr_2O_3 was incorporated into the feedblock at a rate of 3.0 g/kg DM.

RESULTS (Section 3.4.3)

Feed Intakes Sheep 1, 2 and 4 consumed all the hay and feedblock offered. Sheep 3 consumed 0.93 and 0.89 of the total amounts of hay and feedblock offered respectively.

Ru^{103} dosing rate The mean radioactivity (± SE) of the 56 capsules produced was 11.3 (± 0.04) n Ci. The mean dose rates (± SD) for sheep 1,2,3 and 4 from days 1 to 13 were 11.4 (± 0.36), 11.2 (± 0.22), 11.3 (± 0.36) and 11.4 (± 0.26) n Ci respectively.

Time to constant daily faecal Ru^{103} excretion The radioactivity of the daily faecal output as a proportion of the mean daily dose rate for each sheep is listed in Table 3.42 for days 1 - 14 of the experiment.

Table 3.42 Radioactivity of daily faecal output as a proportion of the mean daily dose rate

Day	Sheep 1	2	3	4
0	0.00	0.00	0.00	0.00
1	0.15	0.30	0.10	0.96
2	0.64	0.77	0.58	0.32
3	0.87	1.04	0.78	0.88
4	0.94	0.91	1.02	0.84
5	1.02	0.86	0.90	0.95
6	0.94	0.91	1.00	0.92
7	0.94	0.99	0.89	1.00
8	1.02	1.04	0.73	0.78
9	0.93	1.07	1.04	1.10
10	0.92	0.87	0.93	0.84
11	1.09	1.03	0.95	1.01
12	1.03	0.98	0.89	0.91
13	0.94	1.05	0.97	0.85
14	1.00	0.93	0.76	1.04

The number of days before faecal output of radioactivity was 1.00 of the daily dose rate was 4, 3, 4 and 5 days after the day on which the animals were first dosed for sheep 1, 2, 3 and 4 respectively.

Recovery rate of ^{103}Ru in faeces The recovery rate estimated as the mean daily faecal output of radioactivity from days 6 to 14 as a proportion of the mean daily dose rate of the marker was 0.98, 0.97, 0.91 and 0.94 for sheep 1, 2, 3 and 4 respectively.

Diurnal variation in ^{103}Ru radioactivity in faeces The radioactivity of the marker (counts/g DM) for each 3-hour collection period was expressed as a proportion of the mean radioactivity (counts/g DM) of the faeces for the 24 h period in which each collection was made. The results for the two 24 h periods for each sheep are illustrated in Fig. 3.15. Mean values were calculated for the 4 sheep for corresponding collection periods on the 2 consecutive days (see Table 3.43).

Table 3.43 Faecal Ru^{103} activity in samples taken at 3-hourly intervals as a proportion of the mean radioactivity over 24 hours (Means of 8 observations)

Collection Period	Radioactivity as a proportion of daily mean	SE
0900 - 1200 h	1.04	0.029
1200 - 1500 h	0.94	0.010
1500 - 1800 h	0.91	0.028
1800 - 2100 h	0.87	0.010
2100 - 2400 h	0.94	0.027
2400 - 0300 h	1.07	0.027
0300 - 0600 h	1.13	0.017
0600 - 0900 h	1.06	0.016

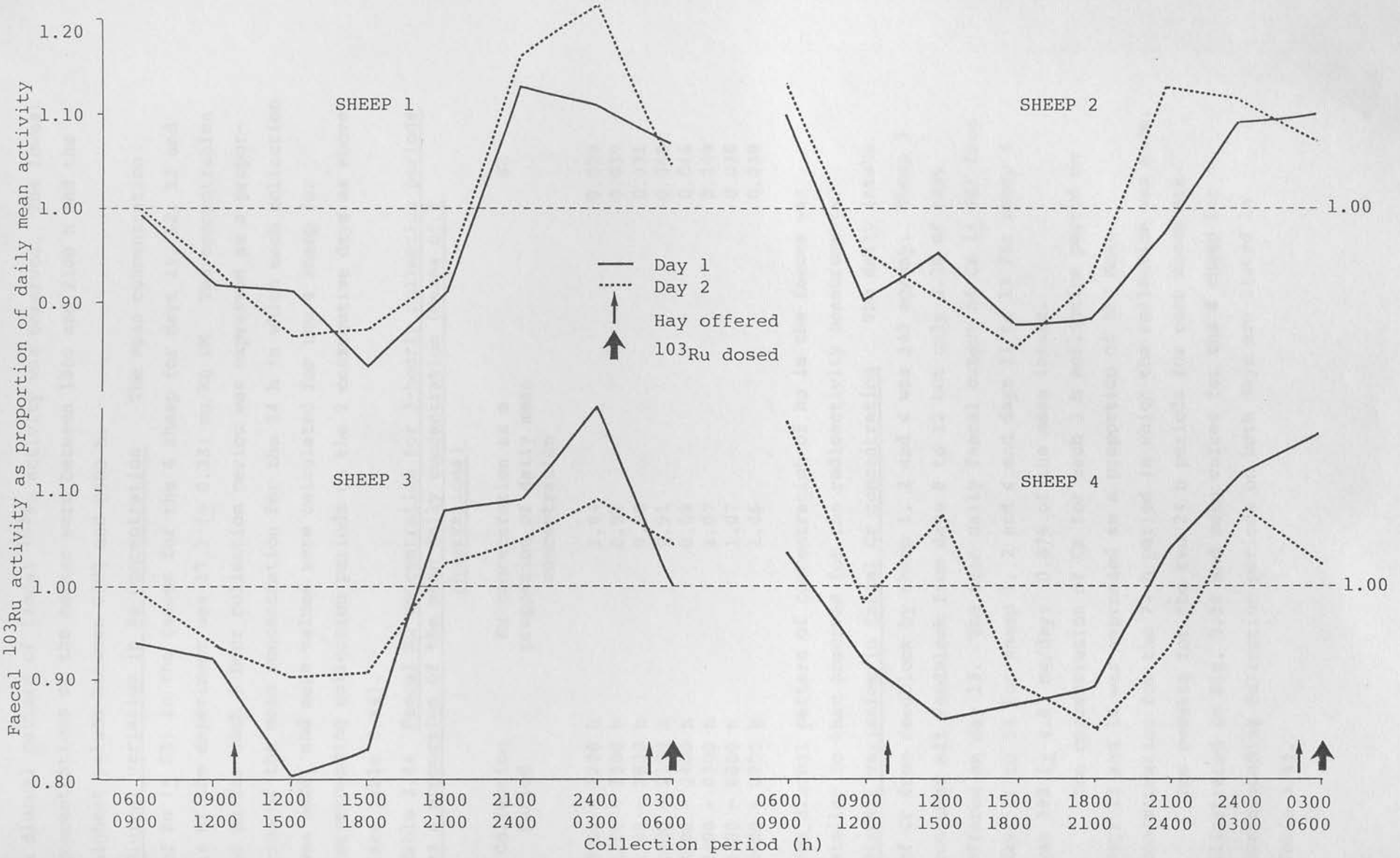


Figure 3.15 Pattern of diurnal variation in faecal ^{103}Ru activity for 2 days for each sheep in Experiment 4.

A diurnal pattern of faecal ^{103}Ru activity was observed. The lowest concentrations of the marker were between 1800 and 2100 h and the highest values between 0300 and 0600 h.

Diurnal variation in Ru concentration The mean concentration of Ru (± SE) in the faeces for the 4 sheep for days 11, 12, 13 and 14 of the experiment was 17.7 (± 0.33) mg/kg DM. The concentration of Ru for each 3 hour collection period was expressed as a proportion of the mean concentration for the 24 h in which each collection was made, and mean values were calculated for the 4 sheep for corresponding collection periods on the 2 consecutive days as above (see Table 3.44).

Table 3.44 Faecal Ru concentration for 3-hourly collection periods as a proportion of the mean daily concentration (Means of 8 observations)

Collection Period	Ru concentration as a proportion of daily mean concentration	SE
0900 - 1200 h	1.04	0.024
1200 - 1500 h	0.97	0.039
1500 - 1800 h	0.90	0.031
1800 - 2100 h	0.91	0.040
2100 - 2400 h	0.88	0.046
2400 - 0300 h	1.07	0.049
0300 - 0600 h	1.07	0.036
0600 - 0900 h	1.06	0.038

The diurnal pattern of concentration of Ru in the faeces was similar to that observed for the radioactivity measurements.

Diurnal variation in faecal Cr concentration The daily intake of Cr from feedblock by sheep 1, 2 and 4 was 340 mg/day. Sheep 3 consumed all feedblock from days 8 to 12 but only 0.78 of that offered on day 13. The mean daily faecal output of Cr (± SE) from days 11 to 14 for sheep 1, 2 and 4 and days 11 to 13 for sheep 3 was 298 (± 4.8) mg/day; 0.876 of the mean intake.

The concentration of Cr for each 3 h collection period on days 13 and 14 was expressed as a proportion of the mean concentration for the 24 h period in which the collection was made.

The results for the two 24 h periods for each sheep are illustrated in Fig. 3.16 and mean values for the 4 sheep for corresponding collection periods on both days are listed in Table 3.45.

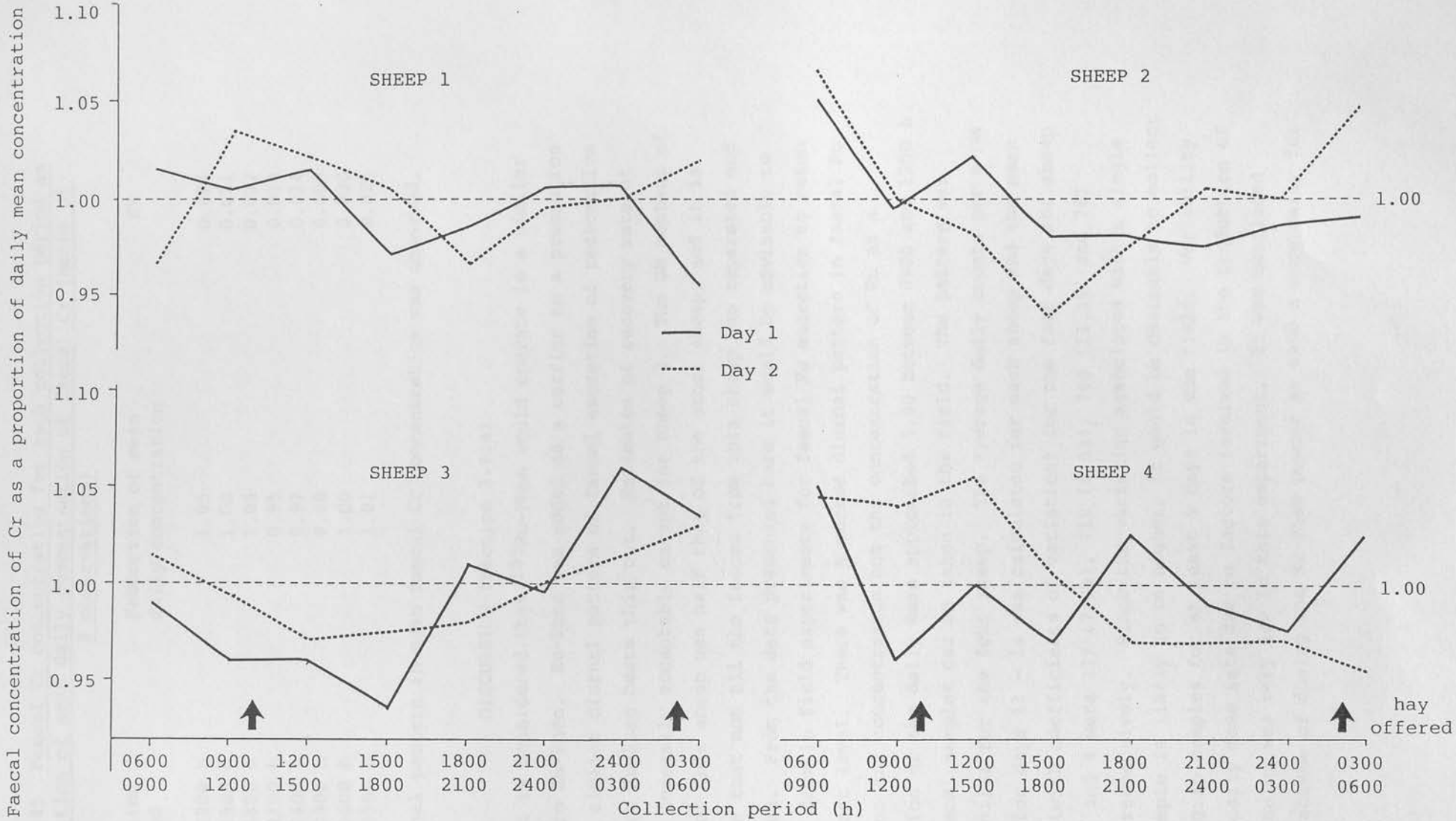


Figure 3.16 Pattern of diurnal variation in faecal Cr concentration for 2 days for each sheep in Experiment 4.

Table 3.45 Faecal Cr concentration for each collection period as a proportion of mean daily concentration of faecal Cr (Means of 8 observations)

Collection Period	Proportion of mean daily concentration	SE
0900 - 1200 h	1.05	0.024
1200 - 1500 h	1.00	0.021
1500 - 1800 h	1.05	0.022
1800 - 2100 h	0.95	0.018
2100 - 2400 h	0.97	0.014
2400 - 0300 h	0.98	0.009
0300 - 0600 h	1.00	0.020
0600 - 0900 h	1.01	0.025

No diurnal pattern in mean faecal Cr concentration was observed.

DISCUSSION (Section 3.4.4)

It is considered that ^{103}Ru-Phen would operate in a similar manner to Ru-Phen. Ru-Phen was added as a carrier as a precaution and the similar diurnal pattern of faecal excretion of radioactive and inert Ru-Phen bears this out. Estimates of recovery rate of Ru were generally acceptable except for sheep 3. The DM content of faeces of this sheep was half that of the other sheep, and it is possible that not all the faeces from this sheep was separated and recovered. From the data presented here it would be advisable to allow 5 days in field experiments for faecal Ru excretion to reach a constant level. There was a marked diurnal pattern in faecal Ru excretion and concentration but the concentration of Ru as a proportion of the daily mean approached 1.00 between 0900 and 1200 h when faecal samples can be taken in the field. The pattern was very similar for the four sheep. The average daily counts per g DM faeces for days 11 - 14 was calculated for each sheep and the mean values (with coefficients of variation) for the four days for sheep 1, 2, 3 and 4 were 737 (7.9%), 719 (6.0%), 740 (11.1%) and 761 (1.6%) respectively. Since the variation associated with a single grab sample is likely to be higher, it would be desirable to collect faecal grab samples for at least 5 days in the field. Variability in the daily dose rate due to factors involved in the production of the capsules was very low in this experiment. It was concluded that a scheme of dosing the Ru-Phen powder at 0900 h once daily for

10 days with faecal grab samples being collected at the same time on the last 5 days would give adequate estimates of faecal output under field conditions.

Cr recovery was low, particularly for sheep 3 (0.811), but only 3 - 4 days of faeces collection were used in its estimation. There was no diurnal pattern in faecal Cr concentration, but there were differences between the two days, particularly for sheep 2 and 4. The animals consumed most of the feedblock as soon as it was offered, but it could have been eaten at any time between meals, which may explain the variable patterns of faecal excretion between days. However, with an intake of 2 meals of feedblock per day, the variation in faecal Cr concentration within the day is likely to be small compared with the high variation observed between sheep and between days for sheep in Experiments 1 and 2.

EXPERIMENT 5: the effects of level of supplement in mid pregnancy and type of supplement in late pregnancy on ewe and lamb performance.

INTRODUCTION (Section 3.5.1)

In Experiments 1 and 2 comparisons were made between treatments where a supplement was offered during mid pregnancy and where no supplement was given. Supplementation in mid pregnancy increased the birthweights of twin lambs in Experiment 1, but had no effect on single or twin birthweights in Experiment 2. More supplementary feeding was given in late pregnancy in Experiment 2 (the reasons for doing so were discussed in Section 3.1.4), but overall liveweight and condition score losses during mid pregnancy were greater, and differences between supplemented and unsupplemented treatments for these variables were larger, in Experiment 1. Thus the lack of response in lamb birthweight might be attributed to differences in mid and/or late pregnancy nutrition. It was, therefore, decided to repeat the comparison between ewes unsupplemented and supplemented in mid pregnancy, offering the same amount of supplement as given in Experiment 2 and to impose two late pregnancy nutritional levels in a 2 x 2 factorial experiment.

When ewes are moderately underfed throughout the mid pregnancy period, placental growth can be retarded (Everitt, 1964; Davis et al, 1981). Mellor (1982) and Davis et al (1981) argued that this may limit lamb birthweight, even though the ewe is well fed in late pregnancy. However, there is some evidence that partial compensation in foetal growth can occur when ewes are well fed in late pregnancy (Everitt, 1966; 1967). Since there was doubt about the adequacy of levels of nutrition achieved in late pregnancy in Experiments 1 and 2, there was a clear need to examine levels of late pregnancy supplementation of ewes grazing a predominantly heather hill. Supplementation allows the opportunity not only to increase the amounts of energy substrates and amino acids available to the tissues, but also allows the balance of substrates to be changed by altering the composition of the supplement.

Increasing the level of protein in the diet in late pregnancy at suboptimal energy intakes has been shown to improve ewe and lamb

performance (McClelland and Forbes, 1968; Robinson and Forbes, 1968; Sykes and Friend, 1972; Clarke and Speedy, 1981). On a predominantly heather hill, microbial protein synthesis in the rumen may be lower than anticipated owing to tannins reducing the availability of dietary N in the rumen (Milne, 1974; MacRae, Milne, Wilson and Spence, 1979). Consequently, although under many circumstances additional undegraded dietary protein would not increase birthweights of single lambs or even twin lambs, in this circumstance the possibility of obtaining responses may well be greater. Moreover, Ørskov and Robinson (1981) pointed out the beneficial effects of diets containing high levels of undegraded dietary protein following a period of negative nitrogen balance in respect of lamb growth, and the importance of amino acids to foetal metabolism of undernourished ewes has been illustrated by Girard, Pintado and Ferre (1979). Consequently it was intended that the two levels of nutrition in late pregnancy would be provided by diets differing in protein supply.

In both Experiments 1 and 2, low ruminal NH_3 concentrations were observed when urea was the principal source of N in the supplement given in mid pregnancy. The concentrations were lower (2 - 3 mM) than those observed by Milne et al (1979) (5 - 6 mM) which were argued to be at a level which would imply optimal conditions for rumen fermentation. Although it is possible that the ewes ate large numbers of small meals of supplement which might lead to a highly efficient capture of N, this is unlikely (see Experiment 7), and indeed Milne et al (1979) found higher ruminal NH_3 concentrations when supplements of sucrose/urea were continuously infused or starch as urea given three times daily. It is thought more likely that urea-N was being ineffectively captured in the rumen. To test this a comparison was made between urea and a vegetable protein source, soya bean meal, which would produce a slower, more sustained release of N.

In Experiment 2, siting of the feedblock had behavioural and nutritional consequences which needed to be investigated further. There were two alternative approaches. The sequences of feedblock placement used in Experiment 2 could be repeated, or feedblocks could be placed on heather or A/F grassland for the entire mid

pregnancy period to quantify animal production responses. The first option was chosen in this experiment.

In Experiments 1 and 2, high supplement intakes occurred after allocation of new feedblocks such that feedblock was unavailable for several days before the next allocation. This is discussed more fully in Section 3.2.4. One method of limiting feedblock intake is the use of containers which prohibit access to the more fragile edges of the feedblock. Kendall (1977) obtained mixed results with the use of containers depending on the type of feedblock used. A comparison was made where feedblocks were supplied either in containers or placed on the ground to determine whether the pattern of supplement intake would be modified.

A high between-animal variability in supplement intake was noted in Experiments 1, 2 and 3. Rapid identification of non feeders would enable those animals to be drawn from the flock and managed separately. A simple device similar to that described by Lobato (1979) was constructed which would mark on the head ewes feeding from the feedblock. It was tested during late pregnancy on one treatment where individual intakes of supplement were measured on all ewes.

In Experiment 1, there was no significant relationship between supplement intake and performance nor any of the plasma variables measured except plasma urea concentration, in spite of a wide range in intake and a consistent ranking in supplement intake over mid pregnancy. This might be because of the low contribution of the supplement to the overall intake of the ewes and to the insensitivity of plasma NEFA and 3-OHB concentrations as indicators of energy status at this stage of pregnancy. With cattle (Nolan et al, 1974) and with sheep (Nolan et al, 1975), grazing poor quality pasture, significant linear relationships were obtained between intake of a molasses/urea supplement and liveweight change, although the amount of variation explained by intake was small. In late pregnancy, the supplement provides a considerable proportion of the ewe's intake. The opportunity was therefore taken to assess the effects of variation in supplement intake during late pregnancy on ewe performance and the plasma variables measured.

MATERIALS AND METHODS (Section 3.5.2)

The experiment was undertaken on the Birnie hirsel at HFRO's Glensaugh Research Station, using the same four plots which had been laid out in 1979 as described in Section 3.1.2. An area of 3 ha of A/F grassland was fenced out of plot 1 and used in Experiments 7 and 8. Plot 1 was 15.5 ha in area and comprised 0.2 A/F grassland, the remainder being predominantly heather, such that each plot now contained the same proportion of A/F grassland.

The effect of 2 levels of supplementary feeding in mid pregnancy and 2 levels of supplementary protein feeding in late pregnancy were examined in one replicate of a 2 x 2 factorial experiment. The levels of mid pregnancy supplementation were no supplementation (L) and a supplement provided by a feedblock (H). In late pregnancy the levels of protein supplementation were provided by a conventional feedblock (E) and by a feedblock containing protein protected against degradation in the rumen (P).

Nested within the experiment two further sets of comparisons were made. In mid pregnancy on the two plots which received mid pregnancy supplementation H, a comparison was made between feedblocks placed on heather vegetation and A/F grassland for consecutive periods. Within this comparison a further comparison was made with the nitrogen in the feedblock predominantly provided by urea (H) or by vegetable protein (HV). The experimental scheme for these comparisons is given in Table 3.46.

Table 3.46 Experimental scheme for comparisons made in mid pregnancy at supplementation level H.

	Treatment HP		Treatment HE	
Period	Feedblock site	N source of supplement	Feedblock site	N source of supplement
21 Jan - 4 Feb	Heather	Urea (H)	A/F	Veg. protein (HV)
5 Feb - 22 Feb	Heather	Veg. protein (HV)	A/F	Urea (H)
23 Feb - 4 March	A/F	Veg. protein (HV)	Heather	Urea (H)
4 March - 9 March	A/F	Urea (H)	Heather	Veg protein (HV)

Treatments LE, LP, HE and HP were allocated randomly to plots 1, 2, 4 and 3 respectively (see Section 3.1.2). The mid pregnancy period lasted from 21 January to 4 March 1982 (median days 54 - 99 of pregnancy) and the period of late pregnancy from 5 March to 8 April (median days 100 - 134 of pregnancy).

Animals

The age distribution of the 186 ewes and gimmers used in the Experiment at October 1981 is given in Table 3.47.

Table 3.47 Age distribution of ewes at October 1981

Age (years)	No. of ewes
2	52
3	55
4	49
5	30

From 28 August until 16 November 1981 all the ewes were grazed on the 4 hill experimental plots with the same stocking rate on each plot. Thereafter they grazed improved pasture, being joined with rams fitted with marker crayons on 19 November 1981. Marked ewes were recorded at 10 and 20 days after joining with the rams. The number of ewes marked in each period is given in Table 3.48.

Table 3.48 The number of ewes mated at 10 and 20 days after the introduction of rams.

	No. of ewes mated		
Age of ewe (years)	1 - 10 days	11 - 20 days	21+ days
2	23	27	2
3	20	32	2
4	13	36	-
5	12	18	-

The rams were removed on 31 December 1981. The ewes were held in a 5 ha area and offered hay ad libitum from 31 December to 20 January 1982 owing to inclement weather. On 21 January the ewes were allocated to the 4 treatments in groups balanced for age, mating date and liveweight. Plots 1, 2, 3 and 4 contained 37, 50, 49 and 50 ewes respectively, and stocking rate on each plot was 2.1 ewes/ha.

Feeds

Mid pregnancy. The feedblocks were made by Rumenco Ltd. to meet the experimental specifications. The same nitrogen content in feedblock H was provided predominantly by urea and in feedblock HV predominantly by soya bean meal. The composition and chemical analysis of the two feedblocks are given in Table 3.49.

Table 3.49 Composition and proximate analysis of supplements used in Experiment 5

	H	HV	E	P
	(proportion on a fresh weight basis)			
Barley	0.500	0.405	0.430	0.430
Urea	0.040	0.015	0.010	-
Soya bean meal	-	0.150	0.100	-
E C feed	0.200	0.200	0.200	0.200
Salt	0.100	0.100	0.100	0.100
Sugar	0.030	-	0.060	0.060
Water	0.075	0.075	0.075	0.075
Mineral/vitamin mix	0.050	0.050	0.020	0.020
White fish meal	-	-	-	0.050
Formaldehyde-treated soya bean meal (Sopralin BP Ltd)	-	-	-	0.060
Dry matter (g/kg)	935	932	966	966
Ash (g/kg DM)	346.4	340.4	272.4	283.1
Nitrogen (g/kg DM)	30.2	30.4	25.5	22.5
Neutral detergent fibre (g/kg DM)	98.8	112.4	88.6	88.6

The shape and weight of the feedblocks was the same as those described in Section 3.1.2. Cr_2O_3 was incorporated into the feedblock at approximately 8.5 g/kg DM. To meet the daily intake of 6 g N and 1.8 MJ ME the ewes were offered 166 g DM of feedblock/ewe. Three feedblocks were provided once weekly and were sited approximately 5 m apart in the middle of A/F grassland or Calluna vegetation areas. Feedblocks on Treatment HE in mid pregnancy were supplied in containers (Rumenco Ltd) which were cylindrical in shape with a solid base and 22 cm high. The ewes had access to only one face of the discoid feedblock when it was placed in a container. Holes were drilled in the bottom of the containers to allow water to escape.

Late pregnancy. The feedblock used in Treatments LE and HE in late pregnancy was formulated to supply 12 MJ ME and 14 g N/kg DM. The feedblock used in Treatments LP and HP was formulated to supply 12 MJ ME and 19 g N/kg DM with 10% soya bean meal and 1% urea in the feedblock used for Treatments LE and HE being replaced by 5% white fish meal and 6% formaldehyde-treated soya bean meal. The composition and chemical analysis of the feedblocks are given in Table 3.49 Cr_2O_3 was incorporated into both feedblocks at 10.5 g/kg DM. The shape and weight of the feedblocks was the same as those described in Section 3.1.2.

Late pregnancy supplementation for Treatments LE and LP was started on 5 March and for Treatments HE and HP from 9 March 1982. From the beginning of late pregnancy supplementation to 1 April 1982 all feedblocks were placed on heather vegetation. From 2 to 8 April all feedblocks were placed on A/F grassland. Feedblocks offered to Treatments LP and HE were provided in containers as described above. Feedblocks offered to Treatments LE and HP were placed on the ground except from 5 - 8 March when feedblocks on Treatment LE were placed in frames. The frames were constructed as shown in Plate 4, such that ewes eating feedblock were marked on the neck by the crayons fitted to the frame. The base of the frame formed a square with sides of 60 cm and the crayons (Sire Sine, Hortico Ltd, Australia) were attached at 40 cm from the ground.

For weeks beginning 5, 12, 19 and 26 March and 2 April, ewes on plots 2, 3 and 4 were offered 3, 4, 5, 5 and 6 feedblocks per week to achieve daily feedblock intakes of 163, 213, 251, 267 and 320 g DM/ewe respectively. Ewes on plot 1 were offered 2, 3, 4, 4 and 5 feedblocks for the same weeks respectively to provide the same daily amounts of supplement per ewe as in the other 3 plots. From 19 March, approximately half the weekly allowance was set out twice weekly, and for the week beginning 2 April a third of the weekly allowance was set out every second day. The animals were removed from the treatment plots on 8 April, and moved to improved pasture for lambing, and given the same supplement in the form of cobs. The supplement (Ewbol Cobs, BOCM, Silcock, Hampshire) was formulated to provide an ME content of 11 MJ ME/kg DM and to contain 140 CP/kg DM.

Plate 4 Crates used for the identification of ewes eating feedblocks

The ewes were offered 320 g DM/ewe/day from 9 April to 10 May 1982.

Management of flock

Decision rules concerning periods of inclement weather were the same as those described in Section 3.1.2. Handling facilities were the same as used in Experiment 1. After lambing the lactating ewes were grazed on improved pasture until weaning on 13 August 1982.

Veterinary procedures were carried out as follows. Ten ewes per treatment were blood sampled on 1 February to monitor the copper status of the flock, which was found to be normal. All ewes were given a Covexin booster injection on 8 March 1982, and all ewes were dosed with Panacur on 8 April 1982. Lambs were dosed with Panacur at approximately 3-weekly intervals from 21 May to 13 August. All ewes and lambs were dipped in July and September as described in Section 3.1.2.

Measurements

Ewe liveweight All ewes were weighed once monthly in October and November 1981, on 14 and 21 January, and thereafter weekly during mid pregnancy and fortnightly in late pregnancy. The ewes were also weighed on 21 May and 13 August 1982. Ewe liveweights were recorded to the nearest 0.5 kg.

Ewe body condition All ewes were condition scored according to the method of Russel, Doney and Gunn (1969) by one operator from 21 January to 8 April 1982, when the ewes were weighed.

Lamb performance Lambs were ear-tagged within 24 h of birth and the same records taken as described in Section 3.1.2. Male lambs were castrated on 21 May 1982 when lamb liveweights were recorded to the nearest 0.5 kg. Lambs were also weighed at weaning on 13 August 1982.

Plasma metabolite concentrations Blood samples were taken from 20 ewes per treatment weekly from 25 January to 5 April 1982, as described in Section 3.1.2. The subsample of 20 ewes was balanced for age, mating date and liveweight. On 22 March, all ewes on Treatment LE were blood sampled. All samples were analysed for plasma concentrations of NEFA, glucose and urea, and for 3-OHB from 5 March to 5 April.

Ruminal fluid concentrations Ruminal fluid was obtained once fortnightly in mid pregnancy from 16 ewes from each of

Treatments HE and HP, and 8 ewes from each of Treatments LE and LP, at the same time as the blood samples. In late pregnancy 8 ewes per treatment were sampled. The procedure was as described in Section 3.1.2. The ewes were chosen at random from the subgroup of 20 ewes used to provide blood samples, and these same ewes were sampled on each occasion. Rumen fluid samples were analysed for the concentration of NH_3 as described in Section 3.1.2.

Estimates of supplement intake by individual animals Grab samples of faeces were taken from all sheep receiving supplements on 4 occasions in mid pregnancy and 2 occasions in late pregnancy. The faecal samples and samples of feedblock were dried at 95° C and analysed for concentration of Cr by the method of Williams, David and Iismaa (1962).

Supplement intake by ewes on Treatment LE in late pregnancy In late pregnancy ewes on Treatment LE were dosed with Ru-Phen as described in Section 3.4.2 from 16 to 23 March 1982, between 1000 and 1200 h daily. Faecal grab samples were taken from the ewes at the same time from 20 - 24 March. Analysis of samples, preparation of Ru-Phen capsules and calculation of supplement intake are described in more detail in Section 3.6.2.

Herbage mass and in vitro OMD of A/F grassland Fifty quadrats were cut to ground level from each plot from areas of A/F grassland from 1 to 7 February 1982, by one operator. Each sample was thoroughly mixed and approximately 10% taken for separation into two categories: (i) A/F and other grasses, and (ii) other species as described in Section 3.1.2. The subsamples were freeze-dried, weighed, and the mass of A/F in the whole sample was determined from the proportion of A/F in the subsample, and the total dry weight of the quadrat. The freeze-dried A/F was bulked on a plot basis for determination of *in vitro* OMD as described in Section 3.1.2.

Statistical analyses

Analyses of variance for the ewe performance, lamb birthweight and lamb performance data were conducted in a similar manner to those described in Section 3.1.2.

The plasma concentration data was divided into 2 sets, one

relating to mid pregnancy and the other to late pregnancy. There were 4 periods during mid pregnancy (2 locations of feedblock and 2 sources of nitrogen), periods 1, 2, 3 and 4 including 2 (25 January, 1 February), 3 (8 - 22 February), 1 (1 March) and 1 (8 March) sampling occasions respectively. Data for ewes unsupplemented in mid pregnancy on 9 March were not included in this analysis. Analyses of variance (EDEX, Hunter et al, 1979) was carried out using a split plot design where periods were subunits and sheep units. Bearing type and time to parturition did not remove significant amounts of the variation for any of the variables examined, and no adjustments were made to treatment x period for these effects. Plasma glucose and urea yielded a skew distribution and the data was transformed ($\log_e$) before analysis. Corrected means and error terms were calculated as described in Section 3.1.2. Where 'F' values were significant, appropriate 't' tests were carried out on treatment, period and treatment x period means. Data for sampling occasions during late pregnancy were analysed as described in Section 3.1.2, with weeks as subunits and sheep as units in the split plot design. Data for supplemented treatments on 9 March was not included in this analysis. 3-OHB and urea concentration values were transformed ($\log_e$) and corrected means and errors calculated as described in Section 3.1.2. Treatment and treatment x week means of 3-OHB concentration were adjusted for time to parturition and bearing type.

A similar analysis of variance was carried out on the ruminal NH_3 concentrations to that described in Section 3.2.2. For the mid pregnancy analysis, data for both non supplemented treatments were combined as a non supplemented group with 16 observations on each of the three sampling occasions. In late pregnancy the ruminal NH_3 concentrations were transformed ($\log_e$) before analysis, and corrected means and errors calculated as described in Section 3.1.2. Where 'F' values were significant, appropriate 't' tests were carried out on treatment and treatment x sampling occasion means.

Supplement intakes of individual ewes in late pregnancy on Treatment LE were regressed against birthweight, ewe liveweight, body condition score and plasma variables after variation associated with age of ewe, bearing type and date of parturition had been

removed as treatment factors. (EDEX: Hunter et al, 1979)

RESULTS (Section 3.5.3)

Herbage mass and in vitro OMD of A/F grassland

Estimates of herbage mass and in vitro OMD of harvested A/F material for each of the four treatment plots are listed in Table 3.50.

Table 3.50 Herbage mass (± SE) and in vitro OMD values for A/F

Plot	Treatment	Herbage mass (kg DM/ha)	in vitro OMD
1	LE	1400(± 188.6)	0.38
2	LP	1830(± 183.8)	0.40
3	HP	1840(± 173.9)	0.41
4	HE	1090(± 135.8)	0.39

The herbage mass of A/F on Treatment HE was lower than that on Treatments LP and HP. The OMD of A/F was similar on all treatments.

Intakes of supplement in mid pregnancy

The mean daily voluntary intake of DM of supplement per ewe (VI; calculated as described in Section 3.2.3), maximum daily DM intake of supplement per ewe within a week and the number of days in each week when a total of less than 5 kg of feedblock remained, are given for Treatments HP and HE in mid pregnancy in Table 3.51.

There was no consistent effect of source of nitrogen in the feedblock on any of the parameters used to describe supplement intake. For Treatment HP the means daily VIs (± SE) were 252 (± 20.0) (n = 17) and 321 (± 28.3) (n = 10) g for the periods when the feedblocks were placed on heather vegetation and A/F grassland respectively. For Treatment HE the mean VIs (± SE) were 210 (± 13.1) (n = 20) and 375 (± 29.4) (n = 8) g when the feedblocks were placed on A/F grassland and heather vegetation respectively.

There was no effect of siting of feedblock on different vegetation types or pattern of siting of feedblock on mean VI, maximum intake or the number of days to exhaustion of the feedblocks. Mean VI was considerably higher than the desired daily intake of 166 g DM/ewe at the start of the mid pregnancy period, and increased over

mid pregnancy particularly for Treatment HE when the required daily intake was 0.38 of the VI. There was no effect of the use of containers on intake parameters.

Table 3.51 Daily intakes of DM of supplement by ewes in mid pregnancy (means of 7 observations, for week beginning 5 March, 4 observations

Week beginning	Treatment HP VI (g DM)	Maximum intake (g DM)	No. days 5 kg of feedblock	Treatment HE (containers) VI (g DM)	Maximum intake (g DM)	No. days 5 kg of feedblock
	Heather vegetation			A/F grassland		
21 Jan	219	299	2	208	282	2
29 Jan	313	374	3	232	274	2
5 Feb	321	398	3	172	241	2
12 Feb	212	315	2	222	324	2
	A/F grassland			Heather vegetation		
19 Feb	282	382	3	354	440	4
26 Feb	368	390	4	354	440	4
5 March	326	407	3*	436	457	4*

* Late pregnancy feedblock supplied from 9 March.

Intake of supplement in late pregnancy

Over the period of late pregnancy the ewes consumed all the supplement offered. Any feedblock remaining when new feedblocks were allocated was not removed. The desired daily intake, the mean daily intake of feedblock by ewes for each week of the late pregnancy period together with the coefficient of variation of supplement intake for each week are listed in Table 3.52.

The high coefficients of variation between days in supplement intake reflected the high voluntary intakes when new feedblocks were allocated . Increasing the frequency of distribution of feedblocks reduced the coefficients of variation in the last weeks of late pregnancy. Intakes of supplement by ewes on Treatments LE and LP quickly reached similar levels to ewes accustomed to supplementary feeding. There was no effect of the use of containers on intake parameters. Voluntary intakes after feedblocks were allocated were lower for Feedblock P, and the mean coefficient of variation between days in supplement intake was considerably lower for P (86%) than for supplement E (111%).

Table 3.52 Mean daily intake of DM of feedblock by ewes (DMI) and coefficient of variation (CV) of supplement intake for each week in late pregnancy (means of 7 observations).

Week beginning	Desired supplement intake (g DM)		Treatment LE	LP	HP	HE
5 March	163	DMI (g)	144	161	163	193
		CV (%)	114	84	135	178
12 March	213	DMI (g)	208	213	218	213
		CV (%)	72	63	89	129
19 March	267	DMI (g)	284	271	272	267
		CV (%)	91	74	90	104
26 March	267	DMI (g)	288	293	272	267
		CV (%)	100	70	85	100
2 April	320	DMI (g)	364	314	328	320
		CV (%)	60	63	58	59

Ewe performance

The pattern of ewe liveweight over mid and late pregnancy for each of the treatments is illustrated in Figure 3.17. The mean liveweight (± SE) on 16 November 1981 was 55.6 (± 0.33) kg. Table 3.53 gives the ewe liveweight changes over the production cycle in which the experiment was carried out.

Table 3.53 Ewe liveweight changes (g/day) (adjusted means)

Period	Treatment LE	LP	HP	HE	Ave SE
16 November 1981 to 21 January 1982 (mating to start of experiment)	- 79	- 80	- 82	- 87	5.0
21 January to 1 March 1982 (mid pregnancy)	- 142	- 188	- 19	- 19	9.0
1 March to 8 April 1982 (late pregnancy)	+ 115	+ 160	+ 38	+ 63	9.4
8 April to 20 May 1982 (early lactation)	+ 128	+ 91	+ 117	+ 140	13.5
20 May to 13 August 1982	+ 9	+ 20	+ 9	+ 13	6.5

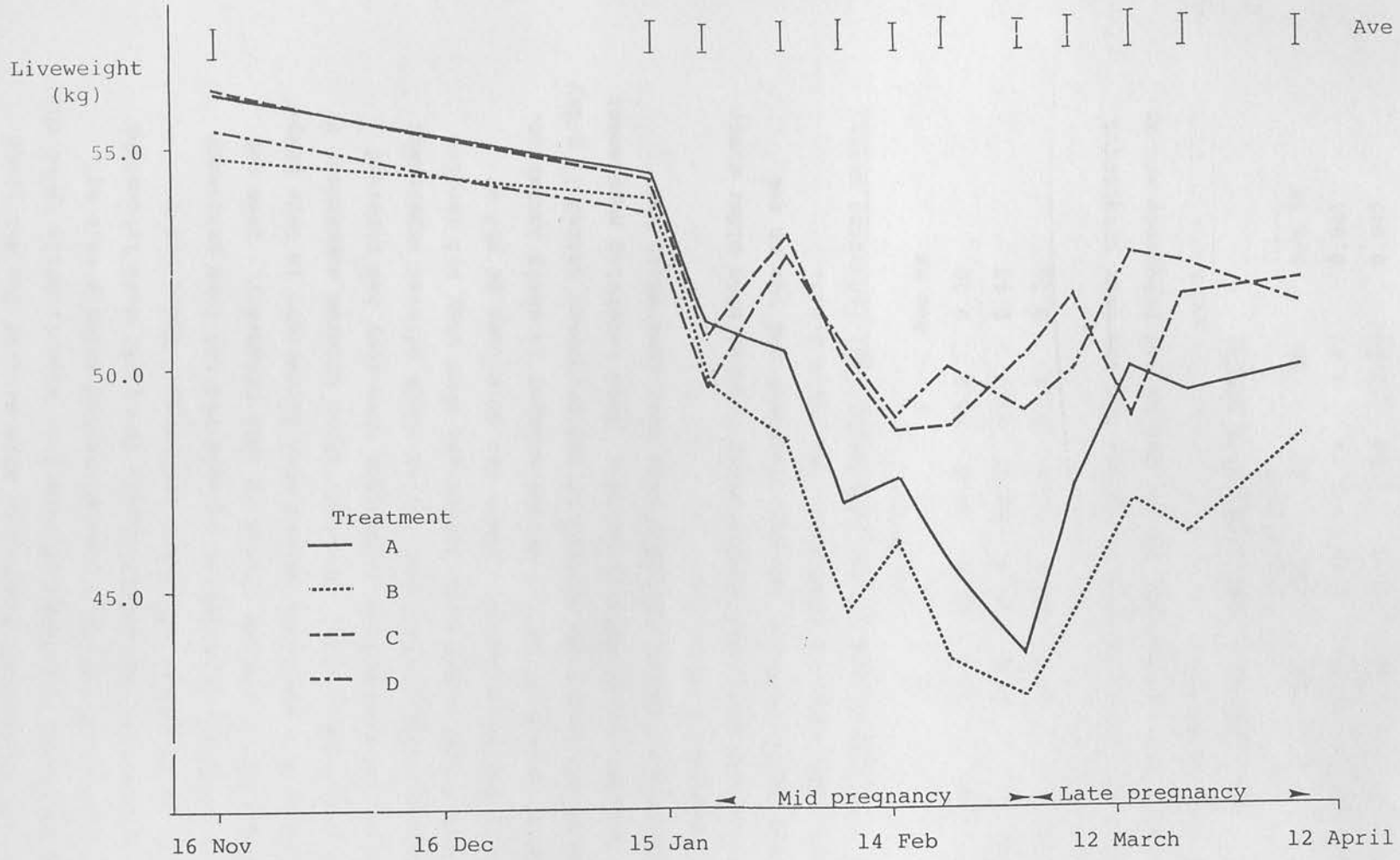


Figure 3.17 Pattern of ewe liveweights during pregnancy in Experiment 5

Ewe liveweight changes between the start of mating and the start of the mid pregnancy treatments were similar for all plots. During mid pregnancy supplemented ewes lost significantly ($p<0.001$) less liveweight (0.74 kg) than unsupplemented animals (6.6 kg). Ewes on Treatment LP lost significantly ($p<0.05$) more liveweight than animals on Treatment LE in mid pregnancy. There was a significant ($p<0.01$) interaction between mid and late pregnancy feeding levels on liveweight change in late pregnancy. Ewes not supplemented in mid pregnancy gained more liveweight in late pregnancy than those which were. However, those offered supplement P in late pregnancy gained more liveweight when they had received no mid pregnancy supplementation, whilst those offered supplement E in late pregnancy gained more liveweight when they did receive mid pregnancy supplementation. There was no effect of mid or late pregnancy treatment on liveweight changes in early lactation. In late lactation ewes supplemented in mid pregnancy gained 17 g/day less than unsupplemented ewes ($p<0.05$). Ewes receiving supplement E in late pregnancy gained 19 g/day less than ewes which had received supplement P ($p<0.05$).

Two-year-old ewes were consistently lighter than older ewes, but there was no interaction between treatment and age on ewe liveweight at any stage of pregnancy (see Table 3.54).

Table 3.54 Effect of age on ewe liveweight (kg) (adjusted means)

	age(years)				
Date	2	3	4	5	Ave SE
16 November 1981	49.2	56.6	59.8	58.2	0.70
1 March 1982	40.6	46.7	52.1	49.1	0.67
8 April 1982	43.3	50.8	55.4	53.4	0.70

Table 3.55 lists the mean CS values for the four treatments at the start of the experiment, at the end of mid pregnancy and at the end of late pregnancy.

Table 3.55 Ewe condition score (adjusted means)

	Treatment				
Date	LE	LP	HP	HE	Ave SE
21 January 1982	2.49	2.42	2.44	2.47	0.045
8 March 1982	1.86	1.83	2.14	2.20	0.047
8 April 1982	1.69	1.55	1.88	1.80	0.054

CS values were similar for all groups of ewes at the start of the experiment. By the end of mid pregnancy, ewes on supplemented treatments had a CS value which was significantly ($p < 0.001$) higher (0.30) than unsupplemented animals. At the end of late pregnancy, ewes which had been supplemented in mid pregnancy retained their advantage, having a CS value which was 0.22 higher ($p < 0.001$) than unsupplemented ewes. There was no interaction between mid and late pregnancy treatments on condition score.

There were small differences between ewes of different ages in CS value at the start and end of mid pregnancy and at the end of late pregnancy, but there was no interaction between age of ewe and treatment on condition score at any time during pregnancy.

Individual values for ewe performance data are listed in Appendix Table A 18.

The number of lambs at birth, on 20 May and 13 August 1982, together with the number of ewes which were barren, are listed for each treatment group in Table 3.56

Table 3.56 Ewe and lamb performance

	Treatment			
	LE	LP	HP	HE
No. ewes at 8 April 1982	37	50	49	50
No. ewes barren	4	4	5	7
No. lambs born	45	73	65	55
No. lambs born alive	42	63	62	53
No. lambs at 20 May 1982	39	55	58	48
No. lambs at 13 August 1982	34	45	54	45

There was no significant difference between treatments in the number of barren ewes (11%) or the number of lambs born per ewe (lambing rate 1.18). Of the ewes classified as barren, 2 ewes from Treatment LE and HP, 1 ewe from Treatment LP and 3 ewes from Treatment HE either aborted or lambed decomposing foetuses at term. Of the 10 lambs stillborn on Treatment LP, 3 deaths were attributable to dystocia. One lamb on Treatments LE and LP and 3 lambs on Treatment HE were considered to have died from starvation and/or exposure within the first week of life. The overall weaning rate was 0.98.

Lamb performance

The birthweights of single and twin lambs for each treatment are given in Table 3.57 together with the combined data for single and twin lambs. For single lambs there were significant effects ($p < 0.05$) of date of birth and age of ewe on lamb birthweight. Lambs born in the first 2 weeks after the start of lambing were 0.6 kg lighter than those born in later weeks, and lambs born to 2-year-old ewes were 0.8 kg lighter than those born to older ewes. For twin lambs there was a significant effect of date of birth on lamb birthweight. Lambs born in the first 2 weeks after the start of lambing were 0.4 kg lighter than lambs born in later weeks.

Table 3.57 Lamb birthweights (adjusted means)

	Treatment				
	LE	LP	HP	HE	Ave SE
Single lambs (kg)	3.37	3.48	3.97	4.01	0.159
Twin lambs (kg)	3.12	2.84	3.21	2.95	0.095
Combined (kg)	3.21	3.24	3.61	3.61	0.100

There was no significant effect of late pregnancy supplementation on lamb birthweights of single or twin lambs or when the data were combined. However, mid pregnancy supplementation increased the birthweights of single lambs by 0.58 kg, of twin lambs by 0.19 kg ($p < 0.01$) and of the combined data by 0.38 kg ($p < 0.01$). There was no significant treatment x age of ewe interaction.

Table 3.58 Lamb liveweight gains in lactation (g/day) and weaning weight of lambs (kg) (adjusted means)

	Treatment				
Date	LE	LP	HP	HE	Ave SE
Birth to 20 May	256	260	273	250	4.9
20 May to 13 August	177	157	172	177	5.0
Liveweight at 13 August	25.8	24.0	25.3	26.4	0.49

Growth rates of lambs between birth and weaning are given in Table 3.58. There was a significant effect ($p < 0.05$) of sex of lamb and rearing type on liveweight gains from birth to 20 May such that by 20 May male lambs weighed 0.9 kg more than female lambs,

and single reared lambs were 2.3 kg heavier than twin reared lambs. Neither mid nor late pregnancy supplementation of the ewes had any effect on the liveweight gain of the lambs. The overall mean liveweight (± SE) at 20 May was 10.8 (± 0.12) kg.

From 20 May to 13 August, female lambs gained 12 g/day more than male lambs, and lambs reared as singles gained 61 g/day more than twin reared lambs ($p < 0.05$). There was no effect of mid or late pregnancy supplementation, but there was a significant ($p < 0.01$) interaction between mid and late pregnancy treatments on lamb liveweight gains from 20 May to 13 August. Lambs from ewes unsupplemented in mid pregnancy gained 22 g/day more when the ewes received supplement E rather than P in late pregnancy, whilst lambs from ewes supplemented in mid pregnancy gained 20 g/day more when supplement P rather than supplement E was given in late pregnancy. There was no significant effect of treatment on weaning weight of the lambs, although lambs born to ewes supplemented in mid pregnancy were 1.0 kg heavier than lambs born to unsupplemented ewes. The interaction between mid and late pregnancy supplementation on lamb growth rate described above manifested itself on the weaning weights of the lambs. Lambs from ewes not supplemented in mid pregnancy were heavier when the ewes received supplement E in late pregnancy, and ewes supplemented in mid pregnancy weaned heavier lambs when supplement P was given.

Individual values of lamb performance data are given in Appendix Table A 19.

Variability in individual supplement intake

Variability between animals is expressed in terms of Cr concentration in the faeces. Table 3.39 lists the mean and the range in faecal Cr concentration, the coefficients of variation of Cr concentration in faeces and the number of animals with faecal Cr concentrations < 200 mg/kg DM for the mid pregnancy period.

There was no difference in the coefficients of variation of Cr concentration in the faeces between feedblocks placed at different sites or feedblock types. The mean coefficients of variation for Treatments HP and HE were 35 and 43% respectively. On most sampling occasions there were one or more ewes that had not ingested

Table 3.59 Mean and range of Cr concentration in faeces, coefficient of variation (CV) and the number of animals with Cr concentration < 200 mg/kg DM faeces over mid pregnancy

	Date of sampling	No. ewes sampled	Mean Cr conc. in faeces (mg/kg DM)	Range of Cr conc. in faeces (mg/kg DM)	CV (%)	No.ewes < 200 mg/kg
Treatment HP	1 Feb	37	1884	0 - 2970	52	1
	15 Feb	36	1719	0 - 2780	35	2
	1 March	33	1647	620 - 2710	30	0
	5 March	38	1489	720 - 2170	24	0
Treatment HE	1 Feb	38	1321	80 - 2410	47	1
	15 Feb	42	1431	0 - 2510	41	1
	1 March	37	1816	120 - 2990	37	1
	5 March	35	1640	200 - 3430	47	0

feedblock. Assuming a faecal output of 650 g DM/ewe/day based on the results of Experiments 1 and 2, and with a Cr concentration in the feedblock of 4200 mg/kg DM, faecal Cr concentrations of 2000 mg/kg DM are equivalent to a daily intake of 310 g DM feedblock. The mean group intakes from feedblock weighings for the 2 days prior to faecal sampling on 1 and 15 February and 1 and 8 March for Treatments HP were 315 (292), 203 (265), 357 (255) and 299 (229) g DM/ewe/day respectively, and for Treatment HE 249 (205), 282 (222), 407 (282) and 436 (254) g DM/ewe/day respectively. The estimated supplement intakes are given in brackets, and in general are lower than those determined from the group intakes.

Table 3.60 gives the means and ranges in faecal Cr concentration, the CV of faecal Cr concentration and the number of animals with faecal Cr concentrations < 200 mg/kg in late pregnancy.

There was no effect of E or P supplement or the use of containers on CV values in late pregnancy. The CV values were in general higher in late than mid pregnancy, reflecting the larger number of ewes having concentrations of faecal Cr of less than 200 mg/kg DM in late pregnancy. Assuming a faecal output of 650 g DM/ewe/day, and with a Cr concentration in the feedblock of 4702 mg/kg DM, faecal Cr concentration of 2000 mg/kg DM is equivalent to a daily intake of 280 g DM/ewe of feedblock.

Table 3.60 Mean and range of Cr concentration in faeces, CV and No. of animals with faeces Cr concentrations < 200 mg/kg DM in late pregnancy

Treatment	Date of sampling	No. ewes sampled	Mean faecal Cr conc. (mg/kg DM)	Range of Cr conc. (mg/kg DM)	CV (%)	No.ewes < 200 mg/kg
LE	8 March	31	2094	10 - 5650	51	1
	5 April	23	2963	440 - 7270	58	0
LP	22 March	39	2814	0 - 5520	48	2
	5 April	37	2114	10 - 5410	73	10
HP	22 March	40	2710	0 - 5800	42	2
	5 April	32	1762	190 - 3570	51	1
HE	22 March	39	2287	10 - 4810	52	2
	5 April	36	1896	10 - 3880	63	2

Use of the marker frame

All the ewes on Treatment LE were marked at the top of the neck with blue crayon apart from one ewe, No. 9102, which had a very faint mark. Faecal Cr concentrations were greater than 1000 mg/kg DM for all ewes except one, whose faecal Cr concentration was 630 mg/kg DM, and for ewe 9102 which had a faecal Cr concentration of 10 mg/kg DM.

Ruminal NH_3 concentrations in mid pregnancy

There was no significant difference between the LE and LP Treatments in ruminal NH_3 concentration, nor any effect of date of sampling. Ruminal NH_3 concentrations ranged from 3 - 4 mM. The ruminal NH_3 concentrations for the supplemented Treatments HE and HP are given in Table 3.61.

Table 3.61 Ruminal NH_3 concentrations in mid pregnancy for ewes on Treatments HP and HE (means of 16 observations)

	Treatment					
	HP			HE		
Sampling date	Feedblock site	N source in supplement	Ruminal NH_3 conc (mM)	Feedblock site	N source in supplement	Ruminal NH_3 conc (mM)
1 Feb	Heather	Urea (H)	2.7	A/F	Veg. prot.(HV)	6.4
15 Feb	Heather	Veg. prot.(HV)	2.9	A/F	Urea (H)	5.4
1 March	A/F	Veg. prot.(HV)	3.7	Heather	Urea (H)	4.7
8 March	A/F	Urea (H)	2.2	Heather	Veg. prot.(HV)	1.9

Ave. SED for comparing Treatments HP and HE for each sampling occasion = 0.39.

There was significant ($p<0.001$) effect of sampling occasion attributable to the low values obtained on 8 March 1982. The low value obtained when the HV feedblock was positioned on heather on 8 March is attributed to a shortage of feedblock. On 7 March at 1000 h, 10.6 kg DM feedblock was present on Treatment HE, but by 0900 h on 8 March, no feedblock remained. On 1 and 15 February ruminal NH_3 concentrations were higher on the treatment where feedblocks were placed on A/F, but there was no consistent effect of block present in the second half of mid pregnancy. There was a significant interaction between source of supplementary N and feedblock position. When feedblocks were placed on A/F, ruminal NH_3 concentrations were greater ($p<0.001$) when vegetable protein was the source of N, but there was no effect of source of N when the feedblocks were placed on heather.

Ruminal NH_3 concentrations in late pregnancy

Ruminal NH_3 concentrations were significantly ($p<0.001$) higher on the second sampling date (5 April, 2.9 mM) than on the first (22 March, 1.2 mM). Concentrations were also significantly ($p<0.001$) higher for supplement E (3.0 mM) than supplement P (1.1 mM).

Plasma concentrations in mid pregnancy

On LE and LP Treatments, plasma urea and NEFA concentrations increased significantly ($p<0.001$) from the beginning to the end of mid pregnancy from 1.44 to 1.79, and from 650 to 876 mM respectively. Plasma glucose concentrations remained constant (3.22 mM). Plasma concentrations of urea, glucose and NEFA for the two supplemented treatments are given in Table 3.62. The data was combined into periods to coincide with block placement and source of supplementary N treatments. Mean weekly values for each treatment are listed in Appendix Table A 20. The pattern of plasma urea concentrations mirrored that of ruminal NH_3 concentrations in that values were low for Treatment HE on 8 March, higher in early mid pregnancy on the treatment where feedblocks were placed on A/F, with no consistent effect of block placement in the second half of mid pregnancy. Source of N had no consistent effect on plasma concentrations of urea, glucose or NEFA.

Table 3.62 Plasma concentrations in mid pregnancy for ewes on Treatments HP and HE (means of 40, 60, 20 and 20 observations for periods 1, 2, 3 and 4 respectively).

Sampling dates	Feedblock site	N source in supplement	Urea conc (mM)	NEFA conc (mM)	Glucose conc (mM)
Treatment HP					
25 Jan/1 Feb	Heather	Urea (H)	1.35	432	3.23
8/15/22 Feb	Heather	Veg. protein (HV)	1.65	702	3.28
1 March	A/F	Veg. protein (HV)	1.77	986	2.93
8 March	A/F	Urea (H)	1.94	760	3.12
Treatment HE					
25 Jan/1 Feb	A/F	Veg. protein (HV)	2.43	605	3.38
8/15/22 Feb	A/F	Urea (H)	2.55	673	3.56
1 March	Heather	Urea (H)	2.46	736	3.04
8 March	Heather	Veg. protein (HV)	1.21	911	3.17
Error VI	(treatments and/or periods)		1.263§	71.8*	1.043§
H	(periods within a treatment)		1.182	54.2	1.057

§ Two means are different ($p < 0.05$) if the ratio of largest: smallest is greater than quoted value.

* Ave SED.

Plasma concentrations in late pregnancy

Mean concentrations of plasma urea, NEFA, 3-OHB and glucose for each treatment on each sampling occasion are given in Appendix Table A 21. Plasma urea concentration was significantly higher ($p < 0.001$) on the last week of sampling than in previous weeks, but there were no time trends with the other variables. Ewe bearing type and time to parturtion explained significant ($p < 0.001$) amounts of variation in 3-OHB concentration. 3-OHB concentration was higher for twin (0.62 mM) than single bearing ewes (0.53 mM), and greater

for those ewes closest to parturition.

Treatment means for the 4 variables over the late pregnancy period are listed in Table 3.63. There was no effect of mid or late pregnancy supplementation treatment or any interaction between the two factors on plasma concentrations of 3-OHB and NEFA (if values for 8 March are excluded). There were significant effects of both mid and late pregnancy supplementation on plasma concentrations of urea and glucose. Plasma urea and glucose concentrations were significantly ($p < 0.001$) higher in late pregnancy when ewes were supplemented in mid pregnancy, and when ewes received supplement E in late pregnancy.

Table 3.63 Mean concentrations of plasma urea, NEFA, 3-OHB and glucose over all sampling occasions in late pregnancy

	Treatment				
	LE*	LP*	HP**	HE**	Ave SE
Urea concentration (mM)	1.16	0.80	1.36	1.45	§ 1.32
NEFA concentration (mM)	722	706	674	644	44.3
3-OHB concentration (mM)	0.51	0.58	0.55	0.58	+ 1.14
Glucose concentration (mM)	3.03	2.95	3.31	3.01	0.056

* Means of 100 observations

** Means of 80 observations

\+ Two means differ ($P < 0.05$) if their ratio (> 1) is greater than tabulated value.

Individual supplement intakes in late pregnancy by ewes on Treatment LE

Supplement intakes by ewes on Treatment LE in late pregnancy are given in Appendix Table A 22, together with the concentration of plasma glucose, urea, 3-OHB and NEFA measured on 22 March 1982, also lamb birthweights, ewe condition score at 8 April 1982 and ewe liveweight change during late pregnancy. Mean DM intake (± SE) for the 37 ewes was 403 (± 44.1) g/day. Supplement intake in late pregnancy explained only non significant amounts of the variation in birthweight, ewe liveweight change and condition score, and plasma variables.

DISCUSSION (Section 3.5.4)

Ewe liveweight at mating, the number of live lambs born per ewe and the incidence of barren ewes in this experiment were similar to those observed in Experiments 1 and 2, although the condition score of the ewes in January was lower in this experiment. Large liveweight and condition losses were sustained by ewes unsupplemented during mid pregnancy compared with those receiving supplementation. This advantage of the supplemented ewes was maintained until the end of pregnancy in spite of greater liveweight gains by treatments LE and LP in late pregnancy. Greater liveweight gains in late pregancy following large losses in mid pregnancy were also observed in Experiment 1. Davis et al (1981) described a similar pattern of liveweight change in late pregnancy when ewes were differentially fed during mid pregnancy. No explanation can be offered since lamb birthweights were lower for the ewes unsupplemented in mid pregnancy, and loss of condition was similar for all ewes in late pregnancy. Surprisingly there was no beneficial effect of higher condition at parturition of ewes supplemented in mid pregnancy on lamb growth rates in early lactation. This is attributed to the high levels of nutrition provided to the ewes during lactation.

Lamb birthweights were similar to those observed in Experiments 1 and 2. Lambs born to ewes supplemented during mid pregnancy were 14% heavier than those of unsupplemented ewes. Though there was no significant interaction between level of supplementary feeding in mid pregnancy and age of ewe, birthweights of single lambs from 2-year-old ewes given supplement in mid pregnancy were 1 kg greater than those of unsupplemented ewes of the same age. Thus it would seem likely that 2-year-old ewes bearing single lambs, and ewes bearing twins are the most likely to benefit from supplementation during mid pregnancy.

The formulation of the two feedblocks in late pregnancy was intended to provide differences in the amount of protein absorbed by including sources of undegraded dietary N in feedblock P. However, from calculations based on similar digestible OM intakes of herbage for both supplement treatments (500 g/day) and taking values of

0.65 and 0.70 for the proportion of digestible OM digested in the rumen, and for the degradability of N feeds other than the undegraded sources of protein in the rumen respectively (ARC, 1980) it is estimated that there was little difference in the amounts of amino-acids absorbed from the small intestine between the two late pregnancy feedblocks. This is because microbial protein synthesis in the rumen would be limited by N supply to a greater extent with feedblock P than E. Evidence for this is the lower ruminal NH_3 concentrations obtained in late pregnancy with feedblock P than E. Furthermore, the higher rumen outflow rates associated with advancing pregnancy (Weston, 1979; Faichney and White, 1980), not taken into account in the calculations above, may have reduced the amount of soya bean meal degraded in the rumen with feedblock E which would further reduce the difference between the quantities of N reaching the abomasum in late pregnancy (Faichney, 1983; Gonzalez, Robinson and Fraser, 1975). Consequently it is not surprising that no differences were observed between the birthweights of lambs on the two late pregnancy treatments. One notable difference between the two late pregnancy feedblocks was the coefficients of variation between days in supplement intake which was associated with lower voluntary intakes when feedblocks were initially allocated. This was probably related to the lower palatability of the feedblock containing the white fishmeal.

Voluntary intakes of supplement were again high during mid and late pregnancy, and increased with time in accord with the findings of Experiments 1, 2 and 3. Ewes unsupplemented in mid pregnancy rapidly reached the desired levels of intake at the start of late pregnancy. Although intrinsic differences in voluntary intake between mid and late pregnancy feedblocks were observed in Experiment 3, this rapid increase suggests that advancing pregnancy also has an important role to play in the greater supplement intakes. There was no effect of nitrogen source during mid pregnancy on intake parameters which contrasts with results of Pearce and Raven (1973) who found that increasing the urea content of feedblocks to 4.5% decreased intakes linearly. However, it may be that other block consituents successfully disguised the bitter taste of urea.

Containers had little effect on voluntary intake, or variability in supplement intake between ewes. The latter was greater during late pregnancy in spite of higher mean intakes, and, as in Experiment 1, reflected the number of ewes with very low intakes. Seven of the ten ewes from Treatment LP which had very low faecal Cr concentrations on 5 April 1982 were 2-year-old ewes.

Although there were few ewes which had low intakes of supplement in the group tested in late pregnancy it seems likely that the marker system used would be useful in practice for the identification of non feeders or those with low intakes. The use of a less persistent dye and a range of colours would enable those ewes to be identified at different stages in pregnancy enabling them to be removed from the flock for closer attention.

The lack of relationships between parameters of performance and intakes of supplement during late pregnancy is surprising since the range in intake of supplement was large. It may be that the intakes measured over one 5 day period are not indicative of mean intake over the entire late pregnancy period. Consistent ranking of intake between individuals was not observed in mid pregnancy in Experiment 2, where feedblock intake was limited (by frequency of supply) as was the case for this group of ewes during late pregnancy. However, no relationship was found between intakes and plasma variables which would be expected to respond to short term changes in nutrient supply. The only other explanation that can be offered is that the feedblocks were placed on heather during 4 of the 5 weeks of late pregnancy. It is likely that animals with very high supplement intakes grazed very close to the feedblocks, and equally possible that those animals with very low intakes spent more time grazing areas of A/F. The quality of the basal diet for these latter ewes could, therfore, have been considerably greater. This, coupled with higher substitution rates of roughage intake for ewes with high supplement intakes might have resulted in the lack of relationships observed.

The failure to detect responses to variation in supplement intake does not reduce the importance of the problem, since the use of the supplement is clearly inefficient. Furthermore, with the variation in supplement intake observed in Experiment 2 and in

this experiment there is a risk of metabolic disorders. Though no cases of pregnancy toxaemia were observed in this experiment, there was a large number of still born lambs, particularly on Treatment LP.

EXPERIMENT 6: the effect of size of area on the intake characteristics of feedblocks by ewes grazing predominantly heather moorland in mid pregnancy.

INTRODUCTION (Section 3.6.1)

The effect of size of area on the intake characteristics of feedblocks by ewes has not been widely studied. Ducker et al (1981) reported a study carried out over a number of hill farms in the U.K. where the ewes grazed areas of 40 to 1214 ha. The large variation in supplement intake observed was related to stocking rate. Decreases in stocking rate were associated with an increase in the number of ewes not eating feedblock, and these ranged from 0.00 to 0.67 of ewes sampled. However, a range of environmental conditions, stocking rates and patterns of feedblock supplementation led to a wide range of intakes, and this makes interpretation of the results difficult. Furthermore, stocking rate of ewes over a hill area is unlikely to be uniform, especially when a range of plant communities, which differ in their nutritive value, are found. There might also be an interaction between stocking rate and siting of feedblocks on supplement intake, depending upon the plant community on which feedblocks were placed.

One way in which increasing the stocking rate could increase variability in supplement intake would be by increasing the chances of non feeders learning from feeding sheep. Graham, Pern and Lineham (1977) reported shared licking of medicated bloat blocks by steers where one animal attracted others to the block. Lobato and Pearce (1980b) noted that, when 4 experienced sheep were mixed with 20 sheep unused to molasses/urea blocks, learning appeared inconsistent. However, the 20 sheep had been brought from range conditions and confined in small yards, and the experienced sheep were only present for the first 2 days of the 3 week experimental period.

In Experiments 1 and 2 where ewes ranged 25 ha plots at 2 ewes/ha there were few instances of ewes not eating. Although 0.11 of ewes in Treatment C in Experiment 1 had not eaten feedblock on the first sampling occasion, all ewes had eaten some feedblock 10 days later and on the 2 subsequent sampling occasions in mid pregnancy. Kendall (1977) reported that the proximity of stock to feedblocks tended to

enhance the intake of feedblock. The method of allocation of feedblock in Experiment 2, which led to extremely variable daily intakes of supplement is consistent with an effect of area size on supplement intake. Since the home range of hill sheep may be as great as 50 ha (Hunter, 1963; Hunter and Davies, 1963) and sheep may walk 8 - 16 km each day (Hafez, 1962), a plot size of 25 ha as used in Experiments 1, 2 and 5 is relatively small. Thus some of the issues raised in this series of experiments could be a function of plot size. The pattern of group intake of feedblock and variability in supplement intake between ewes was therefore compared on two areas of 25 and 140 ha, but where stocking rate, vegetation and pattern of supplementation were similar.

MATERIALS AND METHODS (Section 3.6.2)

The area used for the small area treatment (S) was provided by the 25 ha plot on the Birnie Hirsel on which Treatment HE in Experiment 5 was imposed. The method of feeding the supplement in mid pregnancy, the number of ewes and other aspects of the treatment are described in Section 3.5.2. The Cairn Hirsel at HFRO's Glensaugh Research Station provided an area of approximately 140 ha for the large area treatment (L). The heather-dominant rough grazings on the Cairn Hirsel are of similar vegetational composition to those found on the Birnie hill which were described in Section 3.1.2. The Cairn Hirsel was managed in a similar manner to the Birnie Hirsel (see Section 3.1.2). From 22 January to 11 February 1982, 251 Scottish Blackface ewes were grazed on the hill area. Their age distribution is seen in Table 3.64. The 6-year-old ewes were introduced from another hirsel. All ewes had a full complement of teeth at the start of the experiment.

Table 3.64 Age distribution of ewes on the Cairn Hirsel, January 1982

Age (years)	Number
2	62
3	60
4	51
5	49
6	29

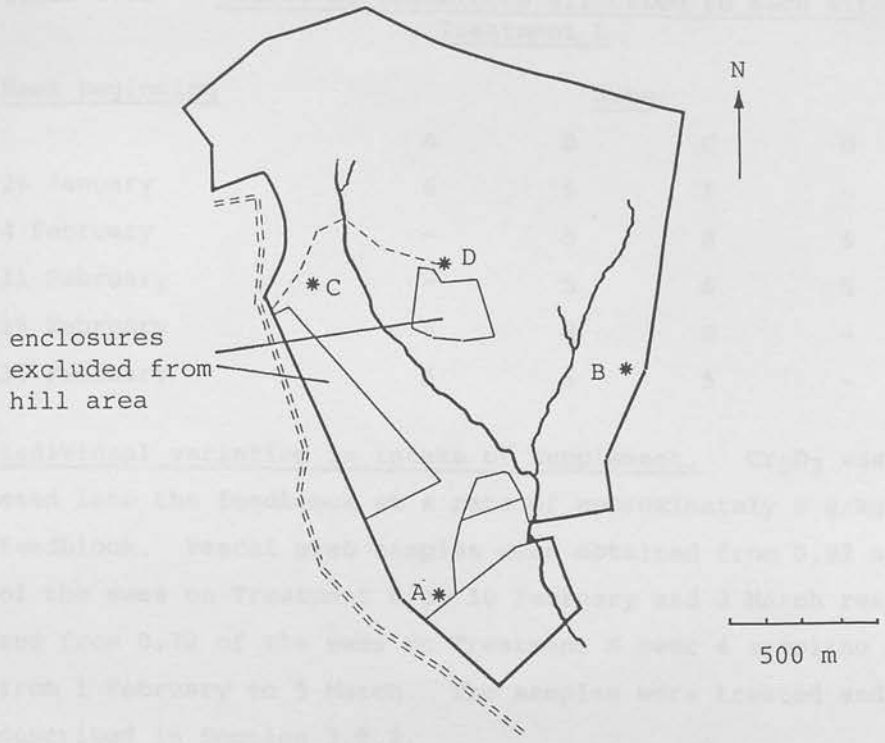


Figure 3.18 Sites of feedblock distribution on Cairn Hill (Treatment L) in Experiment 6.

On 11 February the two-year-old ewes were removed to improved pasture, leaving 189 ewes on the rough grazings. From 26 January to 6 March the ewes on the hill area were offered supplement in the form of feedblocks with the same composition as those offered to Treatment HE in Experiment 5. The feedblocks were allocated once weekly to supply a mean daily intake of 169 g DM/ewe/day from 22 January to 11 February and 235 g DM/ewe/day from 12 February to 6 March. On any one occasion they were located in groups of 5 or 6 at 3 or 4 different sites (see Table 3.65). The sites are shown in Fig. 3.18. The feedblocks were placed in containers as described in Section 3.5.2. Remains of feedblock distributed on 11 February at sites B and C were left to supply the following period starting 18 February. Otherwise the remains of feedblocks were removed when new ones were distributed.

Measurements

Group intake of feedblock The feedblocks were weighed to the nearest 0.5 kg at approximately the same time daily.

Table 3.65 Number of feedblocks allocated to each site on Treatment L

Week beginning	Site			
	A	B	C	D
26 January	6	5	5	-
4 February	-	5	6	5
11 February	-	5	6	5
18 February	6	0	0	-
26 February	6	5	5	-

Individual variation in intake of supplement. Cr_2O_3 was incorporated into the feedblock at a rate of approximately 6 g/kg DM feedblock. Faecal grab samples were obtained from 0.92 and 0.96 of the ewes on Treatment L on 10 February and 3 March respectively and from 0.72 of the ewes on Treatment S over 4 sampling occasions from 1 February to 5 March. The samples were treated and analysed as described in Section 3.4.2.

RESULTS (Section 3.6.3)

Daily supplement intake by ewes

The mean daily amount of feedblock ingested at each site on Treatment L together with the proportion of the initial allocation consumed for each period of feedblock allocation is listed in Table 3.66. Feedblock was always available at one of the sites. At no site was there 7 kg DM available for more than one day except at site C where the total feedblock remaining was 3.6 kg DM on 25 February and none on 26 February. Mean group intakes from 26 January to 11 February and from 12 February to 4 March were 100 and 162 g DM/ewe/day respectively, and the corresponding coefficients of variation between days in supplement intake were 47% and 37% respectively. For Treatment S, mean daily DM intakes were 166 g DM/ewe throughout mid pregnancy. There were 2 - 4 days in each week when there was less than 5 kg of feedblock available. Consequently the mean value for coefficient of variation between days in supplement intake was high (89%).

Table 3.66 Mean daily amount consumed (MI) (kg DM/day ± SD) and proportion of allocation consumed (PC) by ewes on Treatment L.

Week beginning		Site A	Site B	Site C	Site D
26 January	MI	11.9 ± 4.96	3.2 ± 3.17	4.1 ± 3.59	-
	PC	0.96	0.30	0.39	-
4 February	MI	-	8.1 ± 2.77	16.3 ± 6.24	10.3 ± 7.60
	PC	-	0.61	1.00	0.78
11 February	MI	-			10.5 ± 2.87
	PC	-			0.75
	MI		6.5 ± 2.79	7.6 ± 5.63	
18 February	MI	14.4 ± 5.00			-
	PC		PC 1.00	1.00	
	PC	1.00			-
26 February	MI	18.6 ± 7.78	7.8 ± 0.81	13.9 ± 8.49	-
	PC	1.00	0.50	0.89	-

Variation in supplement intake between animals. The mean Cr concentration in the faeces and the number of ewes with less than 200 mg Cr/kg DM in the faeces for each age group for each sampling date for Treatment L is given in Table 3.67. Assuming a daily faeces output of 0.65 kg DM, 1000 mg/kg Cr in faeces is equivalent to an intake of 140 g DM of supplement.

Table 3.67 Mean Cr concentration and number of ewes with 200 mg Cr/kg DM in faeces for each age group of ewes on Treatment L.

	Sampling Date 10 February 1982		3 March 1982	
Age of ewe (years)	Faecal Cr concentration (mg/kg DM)	No. ewes <200 mg/kg Cr	Faecal Cr concentration (mg/kg DM)	No. ewes <200 mg/kg DM
2	551	24	-	-
3	945	8	1131	7
4	879	3	935	4
5	1178	0	1285	0
6	2074	0	1453	0
Ave SE	105.3		98.3	

On 10 February 1982, 10 of the 62 two-year-old ewes sampled had no measurable concentration of Cr in the faeces, while all older ewes sampled had measurable amounts on both sampling occasions. On 10 February, 0.15 of the ewes had less than 200 mg Cr/kg DM in faeces, indicating daily intakes of supplement of less than 30 g DM. Older ewes tended to have higher concentrations of Cr in the faeces indicating higher supplement intakes.

The coefficients of variation of Cr concentration in faeces for Treatment L were 84% and 56% for 10 February and 3 March respectively. The corresponding values for Treatment S were 47%, 41%, 37% and 47% for 1 February, 15 February, 1 March and 5 March respectively. For 1 and 15 February, 0.03 of ewes sampled had less than 200 mg Cr/kg DM in faeces.

DISCUSSION (Section 3.6.4)

Observations suggested that the ewes on Treatment L did not range over the entire area eating feedblocks at all sites, but tended to graze near to one or between two of the feedblock sites. Supplement intake at each site was thus expressed as the amount measured per day, rather than on a 'per ewe' basis, since each site was visited by an unknown number of ewes, which may or may not have eaten supplement elsewhere. Mean flock intakes rose on Treatment L from 73 to 133 g DM/ewe/day for the periods beginning 26 January and 4 February, and from 133 to 210 g DM/ewe/day for the periods beginning 11 and 26 February respectively. Since feedblock was in most instances available at each site, these values can be taken to estimate the voluntary intake of ewes on Treatment L. Thus, Treatments L and S showed a similar pattern in increasing voluntary intakes over the mid pregnancy period. However, voluntary intakes were consistently lower on Treatment L such that, over the duration of this experiment, intakes did not rise above the desired level of intake.

Part of the reason for the lower mean voluntary intakes in January and early February was the low intakes of the 2-year-old ewes. Little or no supplement was eaten by 0.15 of the ewes according to the faecal Cr concentrations on the first sampling occasion. Most of these ewes were 2-year-old ewes, and Cr concentration in faeces of this age group was 0.5 that of older ewes.

Cr concentration in faeces also increased with age on Treatment S, but the magnitude of the effect was much smaller (1262, 1355 and 1947 mg Cr/kg DM for 2, 3 and 4/5-year-old ewes on Treatment S). Ducker et al (1981) noted a similar effect with age of ewe. The difference observed between the young ewes on Treatments L and S cannot be ascribed to differences in previous husbandry, since ewe lambs both had had similar experiences of supplementary feeding; they had been housed in units together, and had been managed in their second summer and autumn in a similar manner. A further possible reason for the lower supplement intakes could have been due to differences in herbage supply between treatment areas L and S. Notwithstanding these possible factors, part of the reason for the lower supplement intakes on the larger area is likely to have been the size of area itself which would be in agreement with the findings of Kendall (1977) and Lobato and Pearce (1980a) who found that increased proximity to feedblocks enhanced intakes of feedblock.

The lower voluntary intakes and continuous availability of feedblock on Treatment L is likely to have caused the lower between-day variation in supplement intake found on Treatment L than on Treatment S. However, from Table 3.64 it can be seen that amounts consumed from a single site can be highly variable. Thus, if subgroups of ewes tend to graze near and feed at certain sites as suggested above, then between-day variability in intake at a given site on large areas could be comparable to that observed on Treatment S, if voluntary intakes of feedblock were higher.

The greater variability between animals in faecal Cr concentration and hence supplement intake observed on the larger area confirms the finding of Ducker et al (1981). In part this can be explained by the low intakes of the 2-year-old ewes in this experiment. The ranges in faecal Cr concentration for Treatment L (0 - 2800 mg/kg DM) for 10 February (excluding 6-year-old ewes for which there were some very high values, perhaps associated with being introduced to a new heft) and 0 - 3000 mg/kg DM for 3 March were similar to those found for Treatment S. Thus it would appear that the lower coefficient of variation values obtained on the smaller area are mainly due to a reduction in the number of non-feeders and ewes with very low intakes.

EXPERIMENT 7: social hierarchy and intake of supplement among ewes offered supplement in the form of a feedblock.

INTRODUCTION (Section 3.7.1)

Evidence from this series of experiments and from the literature indicates a wide variation in the intake of self help supplements by sheep, and a consistent ranking of intake by sheep within groups. Several factors may be associated with variation in supplement intake, including bearing type, age and size of ewe, teeth status and aspects of social behaviour.

In Experiments 1 and 3 variation in feedblock intake was not associated with bearing type of the ewe (i.e. barren, single or twin bearing) in agreement with the findings of Kendall (1977). Dental status has been found to be important in feedblock intake in some flocks (Kendall, 1977). However, all the ewes in this series of experiments had a full complement of teeth apart from 2-year-old ewes, which would have been in a transition period between milk and permanent dentition. Two-year-old ewes were observed to have lower intakes in Experiments 5 and 6 and by Ducker et al (1981) but this might also be a function of unfamiliarity with the supplement or a reduced ability to compete for the supplement, associated with the size of the animal.

Much of the literature relating social behaviour to supplement intake reports on experiments where the animals compete for a supplement, access to which is limited by time, trough space or allowance, and where large numbers of interactions between animals can be observed. Arnold and Bush (1968) studied non-feeding in groups of sheep, previously unaccustomed to supplements, offered oat grain in troughs. They found that non feeders quickly adapted to eating when they were offered feed separately, which implicates social behaviour as a factor associated with variability in intake.

Arnold and Maller (1974) studied leadership of animals approaching feed troughs and disturbance of sheep around the trough. The supplement (450 g/day, oat grain), was consumed within about 3 minutes. There was considerable disturbance around the trough, particularly where trough space was less than 12 cm/sheep. Although

dominance was observed between sheep, no direct aggression was noted. Where the rate of disturbance was high an increasing proportion of the sheep were non feeders. Lobato and Beilharz (1979) studied social dominance when oats and chaff hay supplements were offered, and found social dominance and supplement intake to be related. In contrast Foot and Russel (1973) found no such relationship, and Hughes (1977) stated that dominance hierarchies recorded from aggressive interactions may not correlate well with competitive order in intake.

The method of assessment of dominance is likely to be important too, since hierarchies are seldom linear (McPhee, McBride and James, 1963; Wagnon, 1965; Dove, Beilharz and Black, 1974). Dominance hierarchy based on the proportion of aggressive encounters won (Beilharz and Mylrea, 1963) may obscure irregularities in the dominance order and a large number of random aggressive encounters need to be recorded. Furthermore, Dove et al (1974) observed that the spacing of sheep in yards was related to rank, and it may be that interactions between sheep are not random, even when confined in a small space.

More recently, Arnold and Grassia (1983) showed that dominance and aggression in cattle were not necessarily related. They constructed a social profile which provided a more elaborate test of competitiveness. Appleby (1983) suggested that chance might in fact be an important factor in the occurrence of linear hierarchies, particularly where an incomplete set of interactions is recorded, and he put forward a method for testing the linearity of hierarchies which has been adopted here.

One of the claimed advantages of self help supplements is that shy feeders are encouraged. Lobato and Beilharz (1979) found no relationship between dominance value and intake of a molasses/urea feedblock. Negligible agonistic encounters were observed at the feedblock. However, Wagnon (1965) found that social dominance was related to the time spent eating a self help salt/cotton seed mixture by range cows, and Friend, Polan and McGillard (1966) and Friend and Polan (1974) related social dominance in cattle to time spent eating when the space at a feed bunker was reduced. Friend

et al (1976) found, however, that supplement intake was not related to time spent eating when an abundance of feedspace was available, since some animals utilized their time at the feeder more efficiently than others.

Evidence in relation to the way that self help feedblocks are used in the UK is very limited. Several reports in the literature link dominance with body size (Dove et al, 1974); Lobato and Pearce, 1979). However, there was no relationship between liveweights and intakes in Experiment 3, where a range of 10 kg was observed in 3 - 6-year-old ewes. This would suggest that social dominance was not an important factor in feedblock intake in this system of management. Thus evidence concerning the importance of social behaviour on the intake of supplements is conflicting, though it is likely that dominant animals have priority when a resource is restricted. Observations were therefore made of the behaviour of ewes around a feedblock, to establish whether a linear hierarchy existed, and whether this was related to time spent at the feedblock and the intake of supplement.

Voluntary intakes of feedblock in mid pregnancy were higher than desired in Experiments 1 and 2. Voluntary intake of a mid pregnancy feedblock was lower than that of a late pregnancy feedblock when the two were offered over the same period of time in Experiment 3. Differences in composition of feedblock as they affected texture were thought to be the likely reason for differences in intake. In this experiment a further comparison is made between a conventional mid pregnancy feedblock and one designed to have greater hardness through changing the manufacturing process. Kendall (1977) found conflicting results in the use of containers as a means of restricting intake of feedblocks. The principle behind the use of containers is that they reduce the surface area available for access. This was examined in Experiment 5, but is included in the comparison of the two feedblocks differing in hardness to further test the means whereby intake could be regulated. Supplement intake and behavioural observations were made for each of the methods of regulating intake.

MATERIALS AND METHODS (Section 3.7.2)

Experimental area and animals

The experiment was carried out on an area of approximately 7 ha of predominantly A/F grassland which had been part of Plot 1 in Experiment 1 (see Section 3.1.2). The area was grazed by 15 Scottish Blackface ewes from 27 January to 7 April 1982. They were selected randomly on 21 January from the flock which provided the ewes used in Experiment 5. All the ewes had a full complement of teeth and except for one 5-year-old ewe had had previous experience of feedblocks. The age distribution is given below:

Age (years)	No.
2	4
3	5
4	4
5	2

On 8 April the ewes were transferred to improved pasture and their management thereafter was similar to that described in Section 3.5.2.

Treatments and feeding

Two feedblocks differing in hardness and one method of restricting feedblock intake were used to create 3 treatments differing in supplement intake potential. The 3 treatments were:

A Feedblock H, used in Experiment 5, offered ad libitum.

B Feedblock HX, designed to be harder than feedblock H, offered ad libitum.

C Feedblock H, placed in a container, and offered ad libitum.

Each treatment was imposed for periods of 10 - 14 days duration consecutively in mid pregnancy and again in late pregnancy. The two treatment sequences were chosen randomly. The allocation of treatments to periods is given in Table 3.68.

In the first 3 periods the feedblocks were situated at the lowest point in the experimental area (Site B) and in periods 4 - 6 at the highest point of the experimental area (Site T). A feedblock was replaced when less than the previous day's intake remained.

Table 3.68 Allocation of treatments to periods

Date (1982)	Period	Treatment
27 January - 12 February	1	A
13 February - 26 February	2	C
27 February - 9 March	3	B
10 March - 18 March	4	C
19 March - 28 March	5	A
29 March - 7 April	6	B

Feeds

Feedblock H was formulated to provide 190 g Crude Protein/kg DM and 9.9 MJ ME/kg DM. Chromic oxide was incorporated into the feedblock at 8 g/kg DM. Feedblock HX was designed by Rumenco Ltd., Burton-on-Trent to be harder but with the same constituents. The container used in Treatment C is described in Section 3.5.2. The chemical composition of the feedblocks is given in Table 3.69.

Table 3.69 Chemical composition of feedblocks used in Experiment 7

	H	HX
Dry matter (g/kg)	935	969
Ash (g/kg DM)	346.4	334.6
Nitrogen (g/kg DM)	30.2	30.7
Neutral detergent fibre (g/kg DM)	98.8	63.8

Measurements

Ewe performance. The ewes were weighed and condition scored fortnightly (Russel, Doney and Gunn, 1969). Lambs were ear tagged within 24 h of birth and records taken as described in Section 3.1.2. Blood samples were taken by jugular vene puncture from all the ewes on one occasion during the second week of each period between 1000 and 1200 h. The samples were treated as described in Section 3.1.2 and analyses carried out to determine plasma concentrations of NEFA, 3-OHB, glucose and urea.

Supplement intake. The feedblock was weighed at approximately the same time each day to the nearest 0.5 kg. Measurements were made of individual ewe supplement intake using a dual marker technique. Cr_2O_3 was incorporated into the feedblock and faecal output estimated using Ru-Phen. The ewes were dosed orally with a capsule

containing Ru-Phen impregnated onto cellulose powder (as described in Section 3.4.2) between 1000 and 1200 h daily for the last 10 days of each period. For the last 5 days of each period faecal grab samples were taken from the ewes at the same time each day. The samples were bulked for each period, dried and ground, and a subsample taken for determination of Ru and Cr analysis by an X-ray spectrophotometric method similar to that described by Evans et al (1977).

Three batches of Ru-Phen adsorbed onto cellulose powder were prepared. For each batch Ru-Phen solution was prepared from 10 g $RuCl_3$ by the method described by Tan et al (1971). Fifty gm cellulose powder was thoroughly mixed with the Ru-Phen solution and allowed to stand overnight. Excess Ru-Phen solution was filtered off and the cellulose with Ru-Phen attached dried at 80°C for 24 h. The dry powder was then thoroughly mixed and 0.40 g weighed into gelatin capsules (10 mm diameter). 44 capsules were analysed for Ru content by the method described by Evans et al (1977). Mean weight (± SE) of Ru-Phen cellulose powder in a capsule was 0.404 (± 0.0010) g. Each capsule contained 15.23 (± 0.154) mg Ru.

Behaviour. The movement of the ewes around the feedblock was recorded during daylight hours by time-lapse photography during the last 5 days of each period. Each ewe was individually identified by means of a plastic marker fitted to a harness worn by the ewe and also by symbols drawn on the fleece using an aerosol animal marker spray. The camera (Kodak Analyst 8mm time-lapse, Eastman Kodak Ltd., Rochester, New York, USA) was mounted on a post (height 1.5 m) approximately 8 m from the feedblock. Photographs were taken at 20 second intervals. The film used was MFX Super Surveillance (Kodak Ltd., Hemel Hempstead) and reversal processed to give transparency film which was viewed with a light box and microscope eyepiece.

Each frame of the processed film was examined. Ewes were recorded as 'present at the site' or not, and whether feeding or not. An assessment was made about interactions between two individuals as to whether one ewe was dominant or subordinate to another ewe. This was based the following two criteria: the dominant

sheep butting or chasing the subordinate sheep and the dominant sheep eating whilst the subordinate sheep waited. In a limited number of encounters, there was no sign of aggression between sheep and they were classed as equals.

The duration and number of meals was determined for each sheep for each period. In a sequence of feeding and non feeding by a ewe, adjacent feeding periods were classified as separate meals if the interval between them was 80 seconds or more.

Statistical analyses

Rank correlations were calculated for time spent eating and feedblock intake in successive measurement periods as described in Section 3.1.2. The dominance hierarchy was tested for linearity by the method of Appleby (1983). Since social dominance was not completely transitive and ewes occasionally won encounters with higher ranking individuals, a dominance value (DV) was calculated for each sheep by the method of Beilharz and Mylrea (1963). The relationships between DV, time spent eating at the feedblock and intakes were tested for linearity or curvilinearity using the MULTREG (Edinburgh Regional Computing Centre statistical package).

RESULTS (Section 3.7.3)

Ewe performance

The mean liveweight (± SE) was 48.7 (± 1.86) kg on 21 January which had increased to 51.7 (± 2.25) on 8 April 1982. Condition score (± SE) over the same period fell from 2.4 (± 0.09) to 1.8 (± 0.08). Two ewes died between 11 and 14 February, and have been excluded from the records other than for the calculation of group intakes. 11 ewes gave birth to live lambs. The mean birthweight of singles (± SE) was 3.3 (± 0.43) kg and of twin lambs was 3.7 (± 0.30) kg.

The mean plasma concentrations of NEFA, 3-OHB, urea and glucose for each period are given in Table 3.70. Values were within the range obtained in other experiments in this series.

Group intake of feedblock

At no time during the experiment was the amount of feedblock remaining at the end of a day less than 95 g DM/ewe. Thus, mean

Table 3.70 Mean plasma concentrations for ewes of NEFA, 3-OHB, urea and glucose (means of 13 observations)

Date	NEFA(mM)	3-OHB(mM)	Urea (mM)	Glucose(mM)
8 February 1982	687	0.51	2.3	3.6
SE	59.9	0.034	0.20	0.13
27 February 1982	849	0.64	3.3	3.4
SE	79.9	0.049	0.40	0.10
8 March 1982	578	0.42	3.5	3.7
SE	50.6	0.039	0.31	0.09
15 March 1982	539	0.43	3.4	3.4
SE	46.6	0.020	0.28	0.06
22 March 1982	908	0.40	3.8	3.2
SE	103.4	0.060	0.23	0.08
5 April 1982	908	0.62	5.5	3.2
SE	151.3	0.072	0.46	0.10

daily intakes can be considered to be voluntary intakes (VI). VI, maximum intake and CV of intake between days for each period of block feeding are used to describe the intake of each feedblock type and the results are given in Table 3.71.

Table 3.71 Voluntary intake (VI), maximum intake of feedblock and coefficient of variation (CV) of feedblock intake between days (figures in brackets are the no. of observations)

Period	Treatment	VI(g DM)	Maximum intake (g DM)	CV(%)
1	A	155 (14)	359	68
2	C	198 (14)	543	66
3	B	227 (11)	420	37
4	C	230 (9)	351	29
5	A	249 (9)	351	28
6	B	189 (9)	259	29

There was no difference in VI between treatments. The mean CV for VI for feedblocks in the first 3 periods (57%) was significantly ($p < 0.001$) higher than the CV (29%) in the final 3 periods. This was reflected in the higher maximum intakes in the first 3 periods.

Individual intakes of supplement

The DM intakes of supplement of the 13 ewes present on each of the sampling occasions is given in Appendix Table A 23. Table 3.72 lists the mean DM intake of supplement and the coefficients of variation between animals in supplement intake for each period.

Table 3.72 Mean daily supplement DM intake and coefficients of variation (CV) in supplement intake for each period (means of 13 observations)

Period	Treatment	DM intake of supplement (g)	CV(%)
1	A	189	81
2	C	221	73
3	B	172	73
4	C	216	51
5	A	278	72
6	B	191	67

DM intakes of supplement remained similar throughout pregnancy and were of the same order as those estimated from the group intakes. There was no significant difference between treatments in DM intake of supplement. There was a significant multiple rank correlation ($W = 0.718$, $p < 0.001$) between the DM intakes of supplement in successive measurement periods. Coefficients of variation in supplement intake were high throughout pregnancy.

Behaviour

The number of daylight hours for which records were taken, the mean time spent eating and the mean number of meals for the 13 sheep observed in all periods, are listed in Table 3.73 for each period of the experiment.

The time spent eating and the number of meals eaten by each sheep in each period are listed in Appendix Table A 24. There was a significant multiple rank correlation ($W = 0.492$, $p < 0.001$) between the time spent eating by sheep in successive measurement periods.

Interactions between all pairs of ewes were observed in most periods. There was no consistent reversal of dominance between pairs of sheep over time. The results of 371 interactions between

Table 3.73 Length of observation period, mean time spent eating (± SE) and the mean number of meals (± SE) per ewe for each period

Period	Treatment	Observation period (h)	Time spent eating(min)	No. meals
1	A	46.0	57.3 ± 7.63	18.6 ± 1.47
2	C	44.5	98.3 ±19.10	24.6 ± 1.89
3	B	34.5	74.7 ± 7.50	23.1 ± 2.39
4	C	45.7	59.3 ± 6.13	16.0 ± 1.25
5	A	35.4	73.7 ± 8.67	14.4 ± 0.98
6	B	44.8	50.0 ± 5.97	12.8 ± 0.86

pairs of ewes are listed in Appendix Table A 25 where 358 interactions resulted in one sheep being deemed dominant, and in 13 interactions where neither sheep was deemed to be dominant over the other. Where the result of interactions between a pair of sheep was not always the same, the sheep which was dominant in most interactions was classed as the dominant sheep. The results are summarised in Table 3.74.

There was a highly significant ($p < 0.001$) linear hierarchy with a coefficient, K, of 0.79. Sheep 8128 (DV 75%), which was dominant in the most encounters was the highest ranking animal, and sheep 148 (DV 19.8%) the lowest.

DV was positively related to liveweight ($r = 0.50$, $p < 0.05$). When relationships between DV, time spent eating and relevant supplement intake were examined, time spent eating was linearly related to DV in periods 2 ($r = 0.67$, $p < 0.01$) and 3 ($r = 0.66$, $p < 0.01$). There was no other significant linear or curvilinear relationship within periods but there was a consistently closer set of relationships between the variables listed above during periods 1, 2 and 3 compared with periods 4, 5 and 6. Feedblocks

Table 3.74 Matrix of dominance relationships between sheep (1 indicates row individual dominant to column individual; 0, column dominant to row individual; ½ indicates relationship unknown or sheep deemed equal

	Sheep No.												
	126	143	148	9105	9113	9119	9126	9157	8104	8128	8136	7107	7152
126		1	1	0	½	0	0	0	0	0	0	0	0
143	0		½	0	½	0	0	0	0	0	0	0	0
148	0	½		0	0	0	0	0	0	0	0	0	0
9105	1	1	1		1	½	0	½	0	0	0	0	0
9113	½	½	1	0		0	0	0	0	0	½	0	0
9119	1	1	1	½	1		0	0	0	0	0	0	1
9126	1	1	1	0	1	1		0	½	0	0	0	0
9157	1	1	1	½	1	1	1		0	0	0	0	0
8104	1	1	1	1	1	1	½	1		0	½	0	0
8128	1	1	1	1	1	1	1	1	1		1	1	1
8136	1	1	1	1	½	1	1	1	½	0		1	0
7107	1	1	1	1	1	1	1	1	1	0	0		1
7152	1	1	1	1	1	0	1	1	1	0	1	0	

were sited at the foot of the plot (Site B) in periods 1 - 3 and at the top of the plot in periods 4 - 6 (Site T). When the data were pooled for each site, both intake and time spent eating at Site B were linearly related to DV ($r = 0.48$, $p < 0.01$ and $r = 0.53$, $p < 0.001$ respectively). There was a quadratic relationship between time spent eating and intake ($r = 0.52$, $p < 0.01$). At Site T, intakes were linearly related to time spent eating ($p < 0.05$) though the degree of association was very low ($r = 0.24$). There was no effect of feedblock type on any of the relationships examined.

DISCUSSION (Section 3.7.4)

Appleby (1985) has suggested that linear dominance hierarchies are less common than generally believed since many of the observed hierarchies may have occurred by chance. He described a statistical test for linear hierarchy (Appleby, 1983) which was used in this experiment. A highly significant linear hierarchy was obtained,

although there were cases where a sheep won an encounter with a normally more dominant sheep. There was a possibility that the time spent at the feedblock prior to the encounter was an important factor in the outcome. Dominance was also affected by the number of sheep at the feedblock, for example, two or more sheep might be joined by a sheep higher up the dominance scale and would not move away. The social hierarchy remained consistent throughout the experiment in agreement with Dove et al (1974) for sheep and Beilharz and Mylrea (1963) with cattle. Dominance value was related to ewe liveweight as observed by Dove et al (1974) and Lobato and Pearce (1979). This is in part attributable to the low liveweights of 2-year-old ewes and their low positions in the dominance hierarchy. Wagnon (1965) made similar observations in relation to young cattle. Appleby (1985) suggested that there is no explanation for the occurrance of dominance hierarchies. However, is is important to know whether social dominance can explain between-animal variations in intake, as this will limit our ability to control it. Before considering the relationships between DV, eating time and supplement intake, some of the limitations of the data should be considered. Some ewes might have eaten supplement at night which would not have been recorded by the camera. Wagnon (1965) found some evidence that range cows of low social rank visited a self help feeder at the extreme ends of the daylight hours. Eating time may have been overestimated in relation to intake, in situations where three or more sheep were around the feedblock, as in these circumstances identification from the camera frames of whether a ewe was eating was difficult.

The relationships between intake, time spent eating and DV were strongest at Site B where the time spent eating per hour of the observation period was 25% higher than at Site T. This was related to an increase in the number of meals (per hour of observation) of 54% coupled with a slight decrease in the length of each meal. There was a greater proportion of shared meals at B. In 0.17 and 0.08 of frames recorded, 2 or 3 ewes were eating at the same site respectively. Corresponding figures for Site T were 0.11 and 0.02 respectively. This difference between sites is

attributed to the topography of the plot which affected grazing pattern in the vicinity of the supplement. It indicates that there was greater social interaction at Site B and this could be reflected in the higher coefficients of variation for supplement intake observed at Site B (76%) than at Site T (63%).

One or more sheep were present at the feedblock for only 0.46 of the daylight hours recorded which suggests that feedblock was not a limiting resource when offered ad libitum in this situation. In spite of this, dominance value explained about 25% of the variation in supplement intake, and contrasts with the work of Lobato and Pearce (1979) who observed very few aggressive encounters between sheep at a molasses/urea block, and where intakes were not related to DV.

In this series of experiments, other sources of variation have been found to be unimportant, for example bearing type, or not applicable, for example dentition. Age of ewes has been found to be important, particularly for 2-year-old ewes, and some of the variation explained by DV will be due to this effect. One factor which has not been considered is preference by individual ewes for feedblock. Goatcher and Church (1970b) recorded wide variability within groups of sheep and goats to a range of solutions including salt and sucrose. Since salt and sugars are both ingredients of feedblocks, preference may be an important source of variability to examine further.

There was no difference in the intakes of feedblock in this experiment. Thus hardness and the use of containers are unlikely to lead on the basis of this evidence to greater control of supplement intake. The lower supplement intakes observed in this experiment compared with previous experiments in this series are attributed to the greater availability of herbage as the experimental area was predominantly A/F grassland.

EXPERIMENT 8: the quality of the diet selected by sheep grazing A/F in winter.

INTRODUCTION (Section 3.8.1)

In Experiments 1 and 2 the considerable differences in herbage allowance of A/F had little effect on the in vitro OMD values of the diet selected by sheep. Herbage masses of A/F ranged from 1000 to 2500 kg DM/ha in January of each year and during the late summer and early autumn the A/F and heather areas were grazed at the winter stocking rate of approximately 2 ewes/ha. In terms of a two-pasture system of production (Eadie, 1978), this stocking rate is in part related to the proportion of improved pasture available for grazing during the summer and late autumn, and to the need to achieve its efficient utilisation. To enable generalisation of these results on diet selection of A/F to a wider context requires the consideration of systems that operate at lower stocking rates and/or utilise hill vegetation in a different manner, for example by reducing grazing of the hill in the autumn and substituting for it the utilisation of additional grazed pasture or grass/heather mosaics. Such system alternatives are outlined by Maxwell, Grant, Milne and Sibbald (1984). To test the implications of such strategies for the quality of A/F selected, two herbage masses (2000 and 3500 kg DM/ha in January) were prepared by applying different grazing pressures in the autumn and were grazed at the same stocking rate (2.4 ewes/ha) throughout mid and late pregnancy. A comparision was also made between this stocking rate and a much lower stocking rate.

There were large differences in the in vitro OMD values of the A/F selected by sheep in Experiments 1 and 2 for which no satisfactory explanation could be found. Differences in the amount of herbage and weather conditions did not offer adequate explanations. It was postulated that the areas of A/F from which the diet was selected were different in the two experiments, and that this might offer a possible explanation. By replicating the experiments at two sites to reflect where the sheep had grazed in Experiments 1 and 2 it was hoped that further interpretation of the results of

Experiments 1 and 2 would be obtained.

MATERIALS AND METHODS (Section 3.8.2)

Treatments

The effect of high (H) and low (L) herbage masses on the diet selected by oesophageal-fistulated sheep, grazing A/F grassland from January to March 1982 was examined. The two levels of herbage mass were obtained by differential grazing of A/F grassland by sheep in the summer and autumn of 1981 as described below. The treatment plots were grazed by 2 sheep for 24 h every 2 weeks to give an overall stocking rate of 2.4 sheep/ha over the experimental period. A further comparison was made between the H Treatment grazed at 2.4 sheep/ha and a treatment (HO) which remained ungrazed until mid March when the diet selected by sheep was assessed. The treatments were replicated at two sites, T and B.

Experimental areas

The areas of A/F grassland were located on the Birnie hirsel which from 22 April to 8 October 1981 had received a total of 619 grazing days/ha provided by dry stock. At each site three plots of 0.06 ha were fenced off. Two plots at each site were selected and allocated randomly to the H and HO Treatments. They were not grazed again until 28 January 1982. The remaining plot in each replicate was grazed in October 1981 for 5 days by 3 ewes to provide an additional 250 grazing days/ha to give a total of 869 grazing days/ha. These plots (Treatment L) were then not grazed until 28 January 1982.

Site T was dominated by bracken. Broad-leaved grasses (mainly Agrostis sp) predominated in an open sward. There was no bracken at Site B. This sward was dense and also contained mainly broad-leaved grasses.

Animals

Four Scottish Blackface 3-year-old wethers were prepared with oesophageal fistulae at least a year before the start of the experiment. They had had experience of similar vegetation to the experimental sites as lambs. They were grazed on a ryegrass sward and supplemented with hay and concentrate between sampling periods. Their mean liveweight was 53 kg.

Measurements

Herbage mass and digestibility of A/F grassland. Four quadrats (1.22 x 0.15m) were cut to ground level in each grazed plot on 28 January, 19 February, 4 and 18 March 1982. Five quadrats were cut on the same dates in each of the ungrazed plots. The sample from each quadrat was thoroughly mixed and a subsample of approximately 25 g wet material taken for separation into live and dead grass material and into non-grass components. The remainder was oven dried. Herbage mass was estimated as described in Section 3.5.2. Samples taken from H plots on 19 February were separated into two further categories (ie fine-leaved (Festuca species) and broad-leaved grasses (Agrostis species)) within the green and dead material categories. The separated portions were freeze dried and the grass components retained for estimation of in vitro OMD as described in Section 3.1.2.

Diet selected by oesophageal-fistulated sheep. Oesophageal extrusa samples were obtained from grazed plots from 4 sheep on 2 days approximately every 2 weeks. Sampling Periods 1, 2, 3, 4 and 5 were on 29 and 30 January, 5 and 6 February, 19 and 20 February, 4 and 5 March and 17, 18 and 19 March 1982 respectively. The procedure and treatment of samples was the same as described in Section 3.1.2, although no separation of extrusa samples was required. All the sheep were sampled on the ungrazed plots at each site on 19 March 1982. Estimation of in vitro OMD was as described in Section 3.1.2. A set of ryegrass, A/F and Eriophorum standards was used.

Statistical design and analysis

A rotational statistical design which allows the removal of between-sheep effects was used and the allocation of sheep to plots for each sampling period is given in Appendix Table A 26.

Analysis of variance was carried out on the OMD data using Edex (Hunter, Patterson and Talbot, 1979). The main part of the experiment (i.e. without values for Treatment HO) was analysed with sheep, site, herbage mass and period of sampling as treatment factors. Mean values for the last 3 factors were adjusted for between-sheep effects. In the final sampling period the mean for

the 4 values on the two HO plots was compared with the adjusted means for the 2 values from the corresponding H Treatments.

RESULTS (Section 3.8.3)

Herbage mass, proportion of live grass material in the sward and the in vitro OMD of harvested material

Table 3.75 describes the herbage mass and the proportion of green grass material in the swards. At the start of the experiment herbage mass on the H Treatment (3490 kg DM/ha) was 70% higher than that on the L Treatment (2060 kg DM/ha). There were site differences with the more dense sward (Site B) having 25% greater herbage mass than the open sward (Site T). The proportion of green grass material was higher on the H (0.13) than the L (0.07) Treatment. Throughout the experiment herbage masses remained almost constant. The proportion of green grass material declined until 4 March but then showed an increase on both grazed and ungrazed plots. On the occasion when, on Treatment H, live and dead grass categories were further divided into broad and fine-leaved species broad-leaved dead material accounted for 0.87 of the herbage mass (see Table 3.76).

The in vitro OMD values for live and dead grass material are given in Table 3.77. Green grass material had a mean in vitro OMD value of 0.60 (range 0.53 to 0.64). Site T (0.62) had higher values than Site B (0.57) and there was an increase in in vitro OMD values of green grass material from 0.57 at the end of January to 0.63 on 18 March. The mean in vitro OMD values for dead grass material was 0.29 with only small differences between sites, treatments or periods.

In vitro OMD of extrusa samples

The adjusted mean in vitro OMD values for each plot in each period are illustrated in Fig. 3.19. There were significant ($p < 0.01$) effects of treatment, period and site on in vitro OMD of the diet selected and a significant interaction ($p < 0.01$) between site and treatment. The mean values for all plots for each period are given in Table 3.78 and mean values for each treatment at each site are listed in Table 3.79.

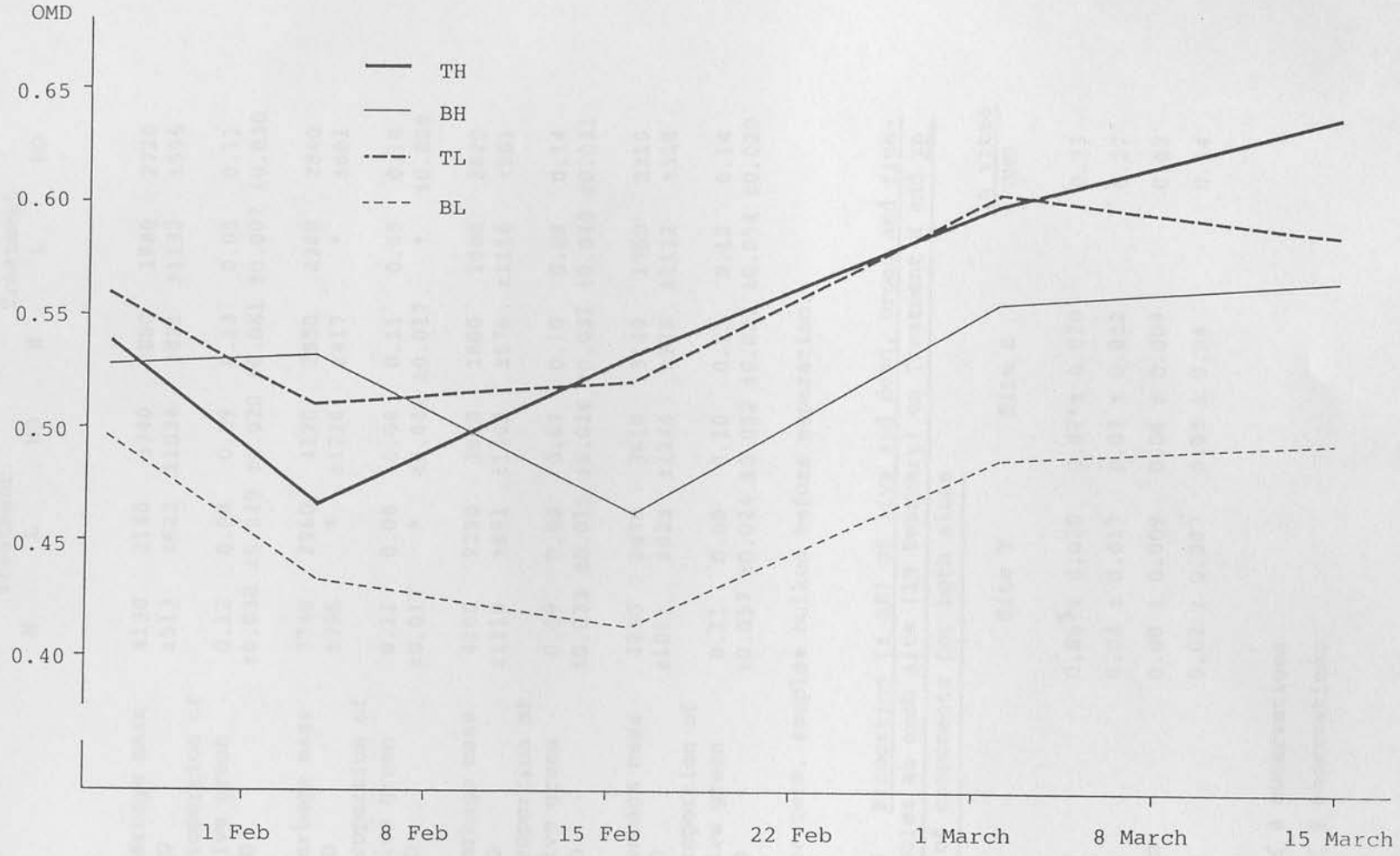


Figure 3.19 The in vitro OMD of œsophageal extrusa samples collected during Experiment 8. (Ave SE = 0·025)

Table 3.75 Herbage mass (kg DM/ha) and proportion of green material (means of 4 or 5 values).

Date of harvest		Site B Treatment H	Site B Treatment L	Site B Treatment HO	Site T Treatment H	Site T Treatment L	Site T Treatment HO
28 Jan	Herbage mass	4130	2140	3340	2850	1980	2720
	SD	±513	±622	±1034	±821	±1132	±596
	Proportion of live green	0.12	0.08	0.09	0.13	0.05	0.11
	SD	±0.038	±0.020	±0.020	±0.061	±0.007	±0.030
19 Feb	Herbage mass	3740	2960	4120	2950	2380	2840
	SD	±796	*	±1726	±417	*	±681
	Proportion of live green	0.11	0.08	0.08	0.11	0.05	0.10
	SD	±0.017	*	±0.041	±0.017	*	±0.028
4 Mar	Herbage mass	4100	2280	3620	1800	1580	2620
	SD	±1116	±891	±1409	±576	±1116	±961
	Proportion of live green	0.09	0.06	0.07	0.10	0.08	0.14
	SD	±0.033	±0.015	±0.016	±0.021	±0.040	±0.031
18 Mar	Herbage mass	4250	2670	3610	3140	1760	2310
	SD	±1061	±825	±1246	±935	±1122	±328
	Proportion of live green	0.11	0.08	0.10	0.13	0.12	0.14
	SD	±0.037	±0.024	±0.052	±0.027	±0.054	±0.029

* No error term, samples bulked before separation.

Table 3.76 Proportion (± SE) of live and dead, broad and fine-leaved species at each site (19 February) on Treatment H and in vitro OMD of components for both sites

Component	Site T	Site B	in vitro OMD
Broad dead	0.86§ ± 0.020	0.87* ± 0.020	0.33
Fine dead	0.04 ± 0.017	0.03 ± 0.012	0.27
Broad green	0.08 ± 0.009	0.06 ± 0.009	0.62
Fine green	0.02 ± 0.007	0.03 ± 0.04	0.54

§ Means of 8 observations

* Means of 9 observations

Table 3.77 OMD of live and dead grass components of harvested material

Date of harvest		Site B Treatment H	Site B Treatment L	Site B Treatment HO	Site T Treatment H	Site T Treatment L	Site T Treatment HO
28 Jan	Live	0.53*		0.59	0.57*		0.62
	Dead	0.29	0.28	0.32	0.27	0.28	0.29
5 March	Live	0.57*		0.61	0.64*		0.66
	Dead	0.29	0.27	0.32	0.27	0.29	0.29
18 March	Live	0.62*		0.64	0.64*		0.65
	Dead	0.30	0.33	0.32	0.26	0.29	0.29

* H and L samples combined because of small amount of material.

Table 3.78 In vitro OMD values of the diet selected in each period (means of 8 values)

Period	In vitro OMD
1	0.531
2	0.486
3	0.482
4	0.552
5	0.574
Ave SE	0.0073

Table 3.79 In vitro OMD values of the diet selected for treatments at both sites (means over 5 occasions)

	Treatments L	Treatments H
Site T	0.548	0.559
Site B	0.468	0.525

Ave SE = 0.004

In vitro OMD values declined from 0.53 in Period 1 to 0.48 in Periods 2 and 3, and then increased to 0.56 in Periods 4 and 5. There was no difference between Treatments L and H at Site T, but at Site B *in vitro* OMD values were 0.06 units higher on the H Treatment.

When Treatments HO and H were compared on 19 March 1982 there was an interaction between treatment and site with the adjusted *in vitro* OMD mean values for Site T being 67.6 and 59.5 and for Site B being 56.6 and 60.0 respectively (Ave SE = 2.35).

DISCUSSION (Section 3.8.4)

Differences of the desired order in herbage mass between Treatments H and L were obtained, although the herbage masses were greater on Site B, positioned where the oesophageal-fistulated sheep grazed in Experiment 2, than on Site T. The proportions of green material were generally similar both between treatments and between sites throughout pregnancy with the proportion decreasing until early March before increasing, presumably reflecting the initiation of the new season's growth. The increase in the proportion of green material in March was mirrored in an increase in its *in vitro* OMD value and in the *in vitro* OMD values of the diet selected. Similar increases in OMD value of the diet selected were observed in Experiments 1 and 2 in late March, and at the beginning of April. The relatively high quality of the A/F ingested in late pregnancy by ewes has perhaps been underestimated in the past.

The *in vitro* OMD values for green and, particularly, for dead leaf were lower than those reported by Eadie and Black (1968) but in their study samples were obtained from ungrazed regrowths of A/F swards cut monthly throughout the winter. Differences in methodology related to the standards used in the *in vitro* procedure might also be important. Prior to the end of February, the proportion of green material in the sward at Site T was similar to or lower than that at Site B. This had been reversed by the end of March (see Table 3.75) which in part explains the higher OMD of extrusa samples collected at Site T. However, higher quality

material was selected at Site T during mid February, and it might be that differences in the sward structure were permitting the fistulates to be more selective where the sward was less dense. The difference between the OMD values of the diet selected in Experiments 1 and 2 cannot therefore be explained in terms of the area from which the diet was selected, since Site B was positioned where the sheep grazed in Experiment 2 when higher OMD values were obtained.

The effect of herbage mass on the quality of the diet selected only manifested itself on Site B where the difference in herbage mass was greatest. In general terms swards with less than 3000 kg DM/ha at the start of the winter with approximately 10% of green material will not allow diet selection differences to manifest themselves at stocking rates of 2 ewes/ha. This supports the conclusions drawn from Experiments 1 and 2. The effect of manipulations of autumn grazing are unlikely to be great unless they produce two-fold differences in herbage mass in January. At a stocking rate of 2 ewes/ha this would imply withdrawing all sheep from the hill for a period of 200 days in the summer and autumn. Under most grazing systems all sheep would graze the hill area for less than 100 days in the summer and autumn. Consequently manipulation of autumn grazing at stocking rates of 2 ewes/ha is unlikely to be a feasible means of manipulating diet quality.

The simulated low stocking rate (HO Treatment) increased the *in vitro* OMD value of the diet selected and, indeed, comparing these values with those of the *in vitro* values of green material suggests that the diet contained 80 - 100% of green material. Thus at low stocking rates and where the proportion of A/F on the hill area is relatively high, a high quality diet can be selected.

CHAPTER FOUR: GENERAL DISCUSSION

Experimental approach and measurements (Section 4.1)

In experiments where resource utilisation is of central concern, as in this study, there are difficulties of methodology. It is not possible to consider the experimental plot as the statistical unit because its size would have to be such that an adequate expression of grazing behaviour could be obtained, and this would require large areas of hill land beyond the resources likely to be made available for research, whether in terms of land or labour. Consequently the animal must be regarded as the statistical unit and, within an experiment, it can be difficult to separate plot and treatment effects. In Experiments 1, 2 and 5, strenuous efforts were made to minimise these between-plot differences.

The whole experimental area was chosen because of its relative uniformity of hill vegetation and its similar aspect and topography. It was mapped carefully and plots created such that in the case of the 0.2 A/F: heather plots, they were as similar as possible. However, there were inevitably differences between plots, for example, in the herbage mass of A/F between plots, with plot 4 having a consistently lower herbage mass than the others. On the basis of comparisons made between herbage allowances of A/F in Experiments 1 and 2, and of the diet of A/F selected in these experiments and in Experiment 8, it is unlikely that this lower herbage mass of A/F in plot 4 would have had a large effect of the nutrition obtained.

To test whether the differences between plots were consistent, the birthweight data obtained in Experiments 1, 2 and 5 were examined, since plot and treatment effects were only slightly confounded The folowing model was used to estimate plot effects by the usual 'least squares' method (GENSTAT V, Rothamsted Experimental Station):

Birthweight = Plot + Year (Experiment) + Treatment + Residual.

The 0.4 A/F plot in Experiments 1 and 2 was excluded from the analysis and any effects of late pregnancy treatments or differences between supplement treatments in mid pregnancy between experiments were ignored.

There were, therefore, 2 treatment factors: supplementary

feeding v no supplementary feeding in mid pregnancy. Differences between plots were calculated as differences from plot 1. The values for plots 2, 3 and 4 were 0.055, 0.138 and 0.053 kgrespectively. The overall treatment difference in birthweight between supplemented and unsupplemented treatments in mid pregnancy was 0.298 kg. Thus plot differences were small in relation to the overall treatment difference in birthweight. Compared with treatment/ birthweight means in individual experiments, the size of the plot effects are sufficiently small not to create significant treatment effects on their own, since the least significance values at the $p<0.05$ level of probability within an experiment are about 0.3 kg. In all statements about the size of the treatment effects there could be a maximum bias of 0.15 kg.

By repeating the same type of treatment on the same area over a period of years, useful information of an indicative nature can be obtained on between-plot differences. However, these differences may vary from year to year, not necessarily in a consistent manner. This is unlikely in this series of experiments as management of both areas and the ewes was similar over the years of the experiments. More direct evidence for the small differences between plots was obtained in Experiment 2, where the ewes were grazed on the experimental plots for 2 - 3 weeks before the imposition of the mid pregnancy treatments. No differences were observed in liveweight of CS change between plots 2, 3 and 4 which could be directly compared, and the evidence of ruminal, plasma and diet selection measurements is interpreted as indicating that plot differences were small at the start of that experiment.

As stated above, the size of the plots and their arrangement on the hill was chosen so that the natural grazing behaviour of the ewes would be unaffected, and in general terms this was the case in that the natural rake of the sheep up and down the hill was maintained. In plot 3 there was more lateral movement across the plot than with the other plots. The size of the plot was also determined by stocking rate and the consideration that approximately 50 ewes per treatment in a field experiment are required to have an 80% chance of showing statistical significance ($p<0.05$) with a

difference of 10% in birthweight. Such a difference would have biological and economic importance. In an attempt to aid interpretation of ewe responses, measurements were made of ruminal and plasma parameters on a representative sub group of the ewes. The degree to which this was successful is worthy of comment.

The samples were taken once daily between 0900 and 1200 h with the ewes being gathered from the hill area from 0 to 1 hours before samples were taken. The ewes were observed to be grazing on most occasions before they were gathered. Supplement as feedblock was often observed being ingested in the daylight hours prior to the ewes being gathered (Eddison, personal communication). Hand fed supplement was given in Experiment 1 after the samples had been taken.

The ruminal samples were taken by stomach tube. Bryant (1964), Lane, Noller, Collenbrander, Cummings and Harrington (1968) and Steger, Voigt and Piatkowski (1968) suggested that sampling technique (via fistulae or stomach tube) and site of sampling within the rumen had effects on the concentration of NH_3 and VFA. Although this could offer an explanation for lower concentrations of those variables in comparison with those obtained indoors (Milne et al, 1979), it does not explain the failure to detect treatment differences in Experiments 1 and 2. Furthermore, when the method of sampling was tested by taking samples by stomach tube and via rumen fistula on 15 occasions over 2 days from a sheep with a permanent rumen fistula and which was offered poor quality hay ad libitum, there was no difference between methods of sampling in the mean concentrations of ruminal NH_3.

The total VFA concentrations and the proportions of acetic, propionic and butyric acid the ruminal fluid were similar to those reported by Mayes and Lamb (1982) for supplemented and unsupplemented animals given similar diets indoors. VFA production rates were estimated from the concentrations using the equations derived by Leng, Corbett and Brett (1968), and these were found to be similar to those measured by Mayes and Lamb (1982). From the relationships between DOM intake and VFA production rate in that experiment, ME intakes were estimated. The additional ME intake of

1.8 MJ/day estimated when supplements were fed in Experiment 2 would suggest that substitution rate was small, in agreement with the indoor feeding work of Milne et al (1979) for heather, and Milne and Spence (unpublished data) for heather and A/F diets. However, the estimated ME intakes were unrealistically low (4.0 to 5.5 MJ/day). An alternative method of estimating ME intakes in the supplemented treatments in Experiment 2 was by applying an indigestibility factor to the faecal output values (570 g DM/day). The choice of an indigestibility factor poses problems in that, although the digestibility of A/F is known and a digestibility value of heather can be assumed with some confidence (Milne, 1974), the proportions of these components in the diet are not known. Attempts were made to measure the proportion of heather in the diet using the method described by Martin, Milne and Moberley (1983), based on the quantitative collections of a simple phenol, orcinol, in the urine using the equipment described by Chambers, White, Russel and Milne (1976). However, because of the large size of the plots and their topography, combined with the need to collect sheep daily, the apparatus was insufficiently robust and, allied with difficulties of urine freezing in the collection tubing, there were insufficient measurements made to warrant inclusion. Assuming a range of indigestibility factors from 0.6 to 0.45 which covers the likely range from 100% heather in the diet and 100% A/F, and assuming the desired supplement intake being completely digested, estimated ME intakes ranged from 7.6 to 13.9 MJ/day. These are considerably higher than those obtained from VFA concentrations, and are considered to be more realistic. In Experiment 2, in mid pregnancy, the supplemented ewes must have been close to energy balance, which would imply an ME intake of approximately 10 MJ/day depending upon the ewe's energy expenditure in relation to environmental conditions. Consequently ruminal VFA concentrations would appear to underestimate ME intake. Reasons may lie in higher rumen volumes in the grazing than in the indoor animals of Milne et al (1979) and Mayes and Lamb (1982), diluting the amount of VFA produced, or in the higher liquid outflow rates in pregnant than non pregnant ewes (Graham and Williams, 1962; Faichney and White, 1980). Support for this later argument comes from the reduction in total VFA

concentration as late pregnancy proceeded, even though total VFA production rate must have increased as increased amounts of supplements were given. Faichney (1983) presented evidence which implies that liquid outflow rates increase as pregnancy advances.

The lack of knowledge of ME intake does produce a limitation on the interpretation of the animal production results which the use of ruminal VFA concentrations of methods of estimation from faecal output and indigestibility do not resolve. A new method of intake measurement has been described by Mayes and Lamb (1984) based on the use as internal markers of n-alkanes found on the culticular waxes of plants. The longer chain n-alkanes are indigestable, or relatively so, by sheep, and because the alkane contents of supplements, heather and A/F have different patterns of concentration, measurement of n-alkane concentrations in faeces could be used to give estimates of intake of these components and the total digestibility of the diet (Mayes, personal communication). Such measurements would have a considerable potential in studies of this nature.

Some of the same considerations discussed in relation to ruminal VFA concentrations also apply to NH_3 concentrations. There is the additional difficulty that changes in ruminal NH_3 concentration associated with feeding, particularly of urea supplements are likely to be more rapid (Milne et al (1979). On unsupplemented treatments and where the feedblock was moved from vegetation to another, the effect of changes in the N content of the diet ingested appeared to be measured by changes in ruminal NH_3 concentration. However, when the amount of urea ingested was increased in Experiment 2 over that used in Experiment 1, and when soya bean meal was compared with urea as the N source in the supplement in Experiment 5, there was little change in ruminal NH_3 values above a low basal level. One of the aims of measuring ruminal NH_3 concentration was to relate these concentrations to ruminal microbial protein production. Satter and Slyter (1974) and Okorie, Buttery and Lewis (1977) described such relations for roughage and concentrate diets with asymptotic values of 6 mM/l for ruminal NH_3 concentration above which microbial protein synthesis did not

increase. It was intended to develop similar relationships in indoor experiments with heather and A/F diets, but generally low NH_3 concentrations observed outdoors made it unlikely that relationships between ruminal NH_3 concentrations and microbial protein synthesis could be developed in indoor studies. It was considered that the daily pattern of ruminal NH_3 concentration should be described in undisturbed sheep to feedblock in the first instance. Farrell, Corbett and Leng (1970) discribed portable equipment for the sampling of rumen fluid from rumen-fistulated sheep, and Mayes and Lamb (personal communication) have developed equipment based on similar principles which allow these measurements to be made.

Measurements of plasma urea concentrations in general followed the same patterns as those for ruminal NH_3 concentration, suggesting that plasma urea reflected the amount of N available in the rumen rather than reflecting catabolism of tissue protein. The values obtained for both plasma urea and ruminal NH_3 concentrations were low, indicating a low availability of N in the diet.

Since it is difficult to measure ME intakes under field conditions, the use of plasma glucose, NEFA and 3-OHB concentrations as indicators of energy status of the ewe in pregnancy has been indicated (Russel, 1978; Mellor, 1983). Both glucose and NEFA concentrations are affected by the stress of handling (Reid and Mills, 1962; Pearson and Mellor, 1976; Russel, 1978). Ewes were gathered frequently, at least once weekly, in Experiments 1, 2 and 5, and appeared to become accustomed to handling, although no measurements were made of plasma catecholamine concentrations which might have indicated the degree to which the animals were stressed.

Flock glucose concentrations in late pregnancy were in the range that Mellor (1983) described as typical of well fed ewes (2.8 - 3.2 mM). However, from the mortality/birthweight curves of the Birnie flock derived from data collected over the 6 years prior to this study (see Fig. 4.1), levels of mortality of approximately 25% would be expected for twin lambs born in this study. According to Mellor (1983), such losses would not have been

anticipated, since the mean glucose concentrations of twin bearing ewes were similar to those of single bearing ewes. Stress can elevate glucose concentration (Pearson and Mellor, 1976), but relationships between glucose flux and concentration are poor, and there are homeostatic mechanisms to control glucose concentration within defined limits except under extreme conditions (Lindsay, 1978).

The direct relationship between the rate of fat mobilisation and plasma NEFA concentration, except at more severe levels of undernourishment, and the established relationships with moderate levels of undernourishment (Russel, 1978) should have made this a useful index in these experiments. However, although there were considerable differences in change in condition score in mid pregnancy between supplemented and unsupplemented ewes in Experiments 1 and 5, no differences in NEFA concentration were observed. It is, therefore, not surprising that the probably smaller changes in fat mobilisation in late pragnency between treatments were not indicated by changes in NEFA concentrations. NEFA concentrations increased as pregnancy advanced in these experiments, indicating that, in a gross sense, differences in undernourishment could be identified. However, different reactions by sheep to the stress of handling or different times between supplement intake and sampling may have been implicated in the varibility in NEFA concentrations observed which limited its usefulness in the context of these experiments.

3-OHB concentrations in plasma are likely to be most useful in late pregnancy when increased gluconeogenesis depletes oxalocetate for oxidation of acetyl CoA, which is derived from free fatty acid metabolism, such that acetyl CoA is converted to acetoacetate and 3-OHB. It also has the advantage of not being so subject to change by handling stress as the other parameters. In section 3.1.4, the difficulties associated with using established relationhips between energy status and 3-OHB concentration were outlined, and in Experiments 2 and 5 the same amounts of feed were given to each treatment in late pregnancy. 3-OHB concentrations on a flock basis remained relatively low in both experiments. In relation to practical situations, the flock mean would be considered to indicate that

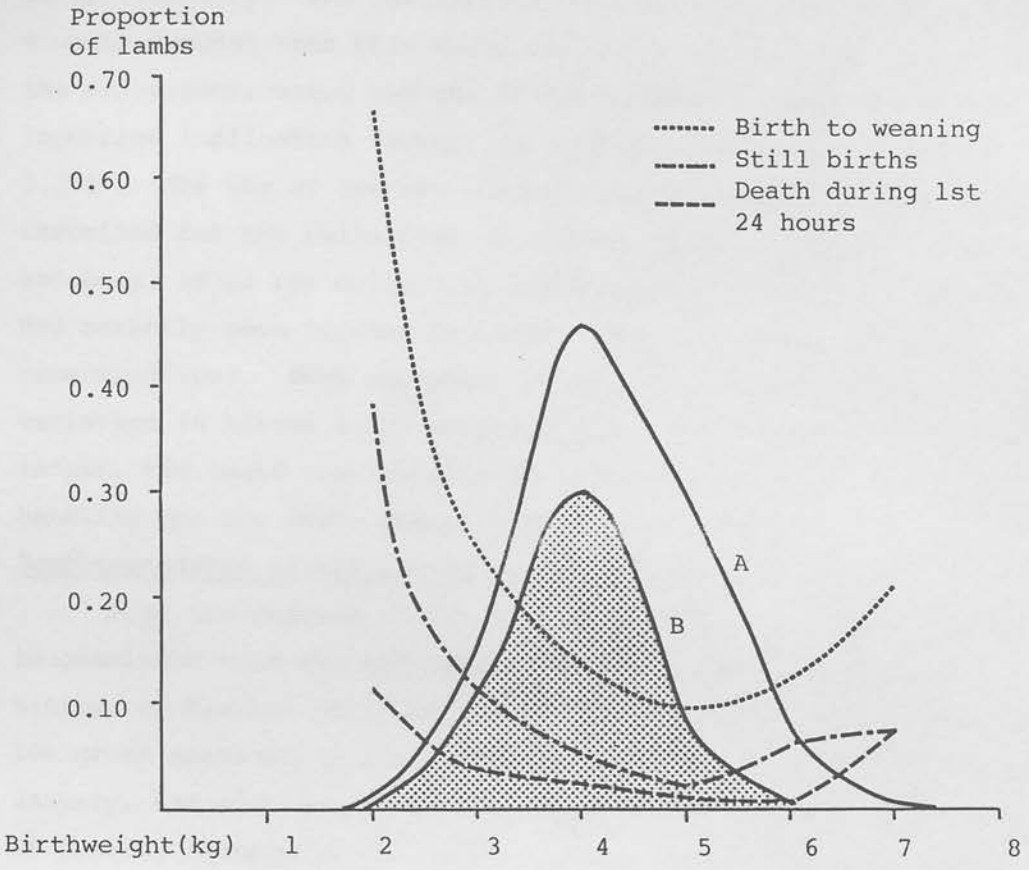


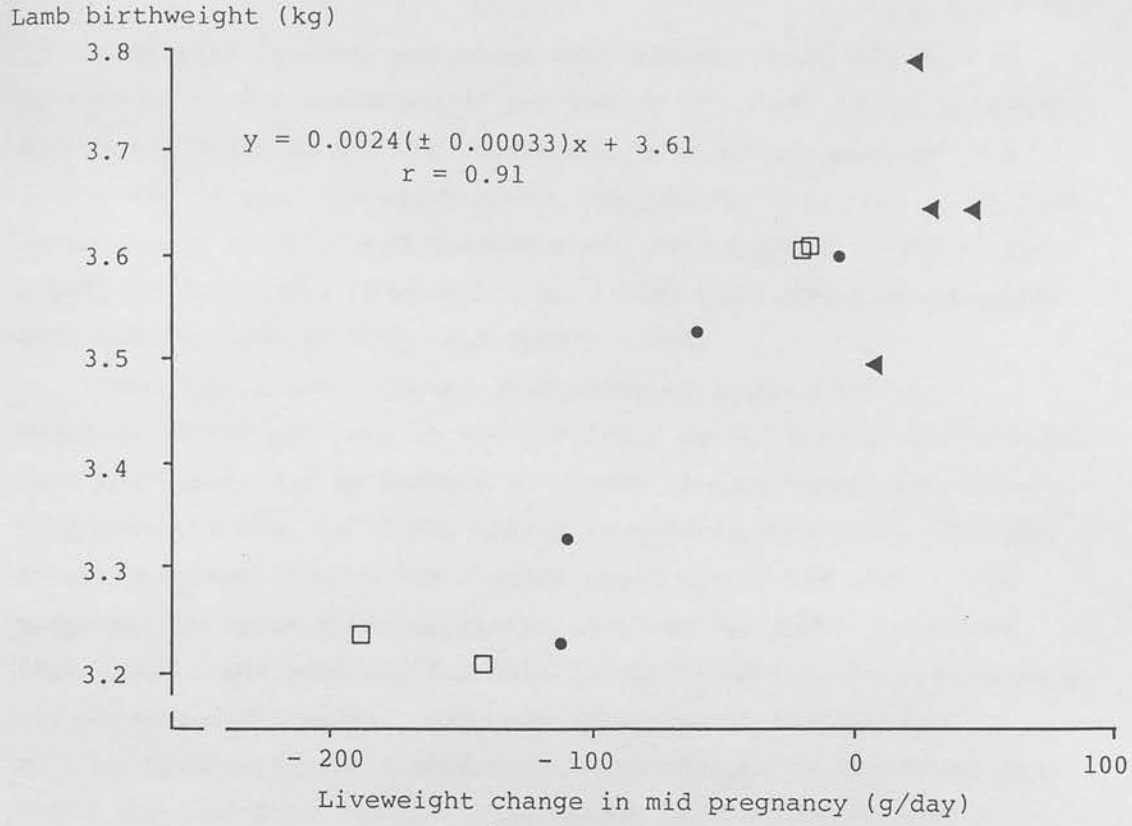
Figure 4.1 Distribution of birthweight classes for Birnie Hirsel 1973 - 1979. (A all lambs, B twins only) and the proportion of deaths within the birthweight classes (a) birth to weaning (b) still births (c) deaths to 24 hours including stillbirths.

flock ewe energy status was adequate, and that birthweights would be satisfactory. The low birthweights of twin lambs in Experiment 5 would suggest that this would not be the case in the conditions of the experiment, where the use of feedblocks is probably the most important implicating factor, as discussed earlier (see Section 3.2.4). The use of similar automatic sampling equipment to that described for the collection of ruminal samples (Farrell, Corbett and Leng, 1970) for collecting blood samples via jugular catheter has recently been further developed (Mayes and Lamb, personal communication). Such equipment would allow a description of diurnal variation in plasma 3-OHB concentrations in relation to supplement intake, and could also be used to avoid stress associated with handling for the other plasma variables discussed.

Supplementation in mid pregnancy (Section 4.2)

From the results obtained in Experiments 1, 2 and 8, it can be concluded that ewe and lamb performance will be generally similar on heather hills with 0.20 to 0.40 A/F grassland containing 10% green material in a herbage mass of less than 3000 kg DM/ha in January, and with stocking rates of 1 to 2.5 ewes/ha. The system of grazing imposed in the summer is unlikely to influence winter nutrition obtained from the A/F grassland. There is no reason to believe that the A/F grassland was in any way atypical of other A/F areas on heather dominant hills, but no information exists on the proportion of dead material or herbage mass of such areas. This information would be helpful to the application of these conclusions.

On such hills, mid pregnancy supplementation over the three years of experimentation (Experiments 1, 2 and 5) increased birthweight by 0.298 kg, based on the analyses described in Section 4.1. However, the responses in birthweight obtained in each experiment were different. In Experiment 1, twin lamb birthweights were higher when ewes were supplemented; in Experiment 2 there were no significant responses in birthweight, and in Experiment 5 there were responses in both single and twin lamb birthweights. Combining the data from the 3 experiments, there were significant linear relationships between lamb birthweight and ewe liveweight ($p < 0.001$) and condition score ($p < 0.001$) change in mid pregnancy. These are illustrated in Fig. 4.2.



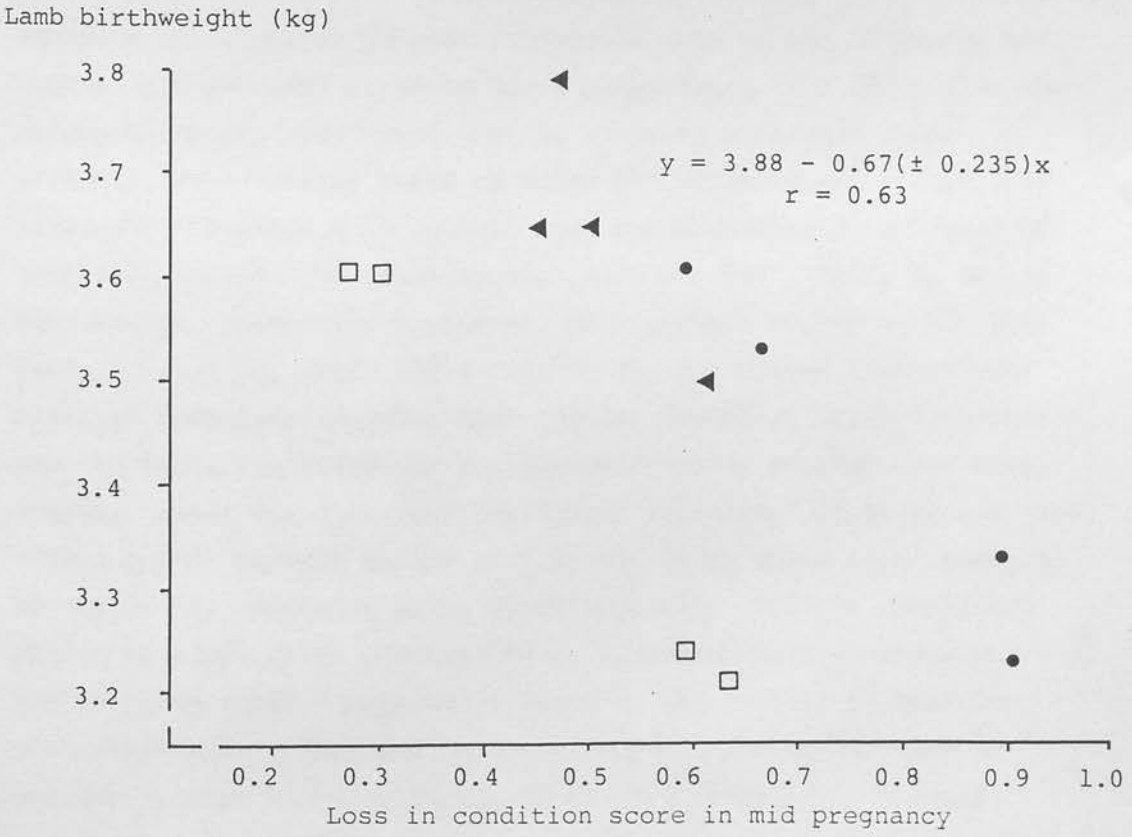
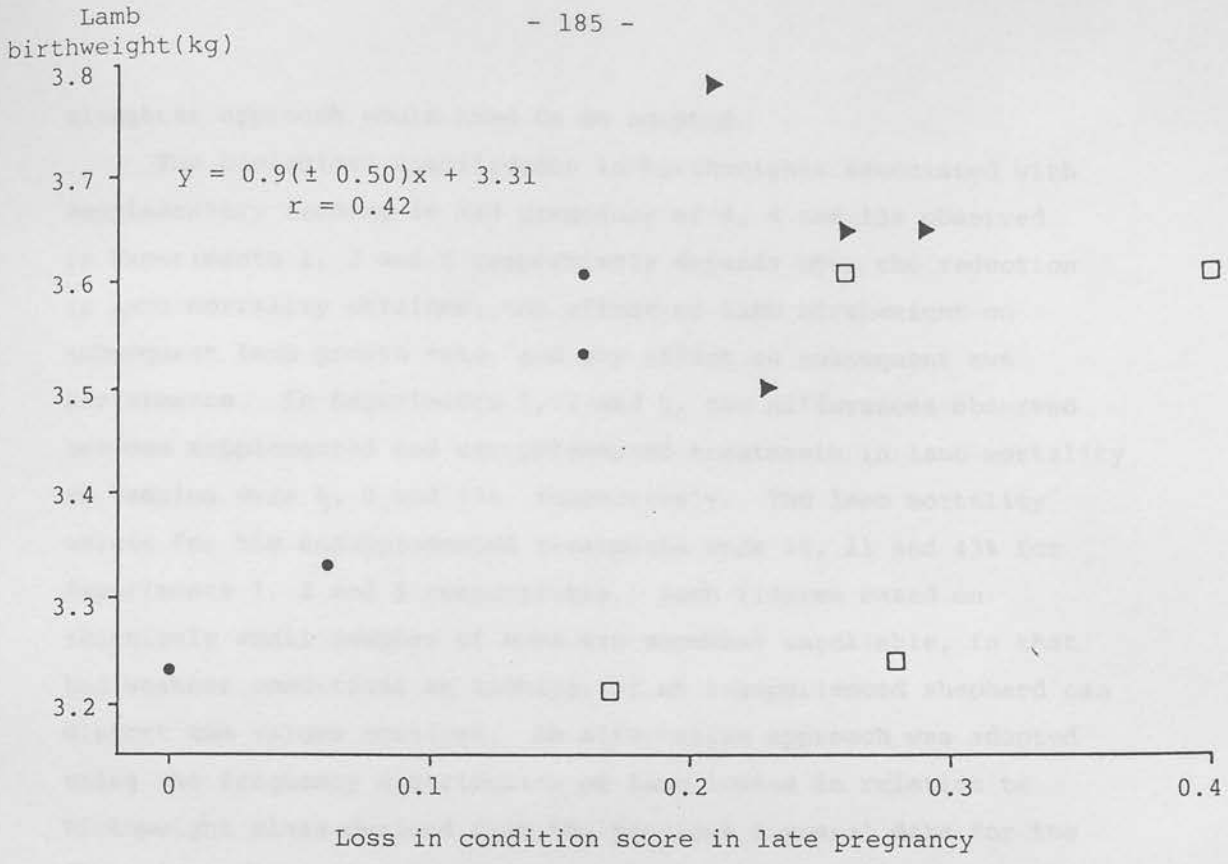


Figure 4.2 Lamb birthweight vs ewe liveweight and condition score change in mid pregnancy (data from Experiment 1, ● ; Experiment 2, ◀ and Experiment 5, □).

The fall in condition score over mid pregnancy was related ($p < 0.001$) to the condition of the ewe at the start of mid pregnancy within supplemented and unsupplemented treatments, such that the higher the initial condition score, the greater the loss. Condition score at the start of mid pregnancy was also related to the birthweight of twin lambs ($p < 0.05$) within each experiment, in agreement with the findings of Clark and Speedy (1980).

The mechanisms whereby supplementary feeding and/or reducing liveweight loss in mid pregnancy could increase birthweight have been descussed in Section 2. These revolve around placental size being limited by either energy or protein substrates absorbed in mid pregnancy, or by fat tissues being spared for use in late pregnancy to spare other nutrients required for foetal growth at that time. Some evidence for this latter theory can be deduced from the present experiments. Although there was no relationship between birthweights and condition score changes in late pregnancy, there was a positive linear relationship between birthweight and the proportion of total body condition score lost in mid and late pregnancy that was lost in late pregnancy (see Fig 4.3). The strong negative relationship between liveweight loss in mid pregnancy and birthweight provides evidence for a prima facie case that it is the supply of energy substrates that is limiting placental size. Moreover, calculations based on total VFA concentrations described previously (Section 4.1) suggest that supplementation increased ME intakes, implying that substitution rate was low. There is little evidence to support the hypothesis that protein supply to the placenta limited its size, since ruminal NH_3 and plasma urea concentrations were low, implying that ruminal microbial protein synthesis was not being maximised for supplemented or non supplemented ewes. However, using the data from the indoor experiment of Mayes and Lamb (1982) and an assumed intake of 9 MJ ME, there would be an increase of 40% in the amount of amino acids absorbed. Further experimentation is required to examine these hypotheses more thoroughly. The 'protein supply' hypothesis would be the easiest to test in that additional undegraded dietary protein could be included in rations without altering energy supply significantly. A serial



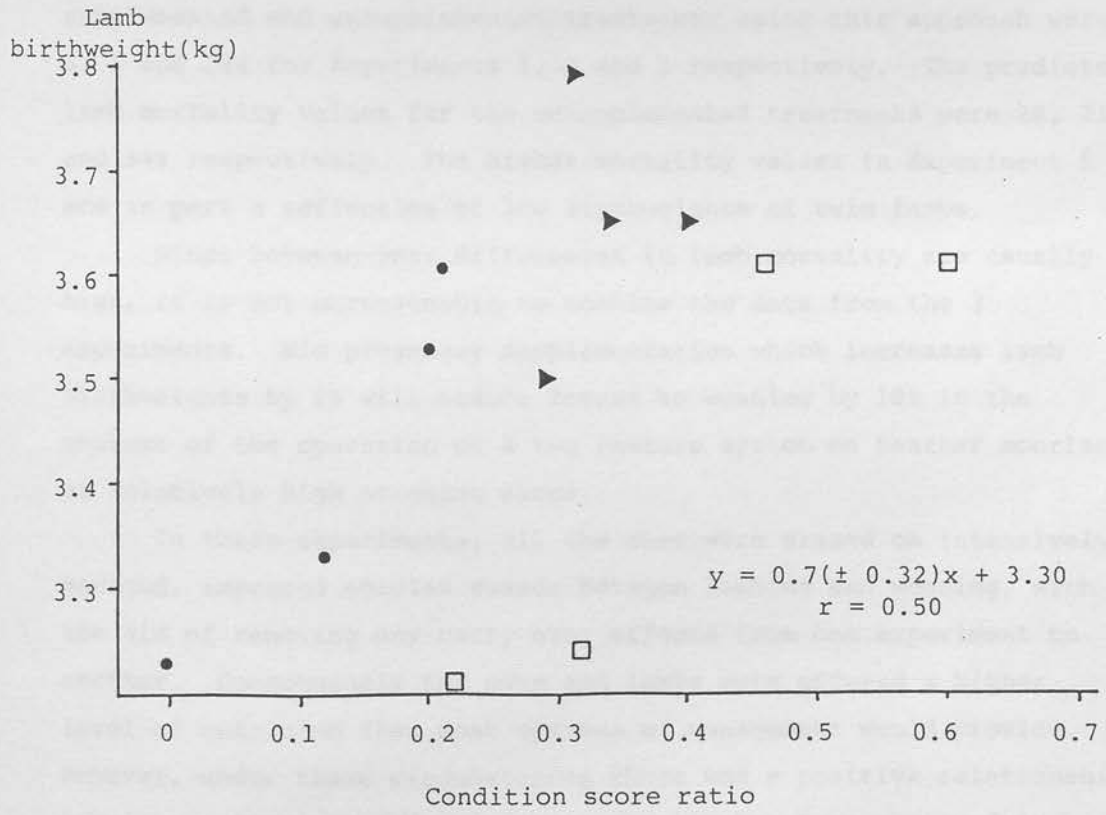


Figure 4.3 Lamb birthweight vs loss in ewe body condition score in late pregnancy and the ratio of loss in condition score, mid pregnancy: loss in condition score, late pregnancy (data from Experiment 1 ● , Experiment 2 ◀ , Experiment 5 □).

slaughter approach would need to be adopted.

The biological significance in birthweights associated with supplementary feeding in mid pregnancy of 9, 4 and 13% observed in Experiments 1, 2 and 5 respectively depends upon the reduction in lamb mortality obtained, the effect of lamb birthweight on subsequent lamb growth rate, and any effect on subsequent ewe performance. In Experiments 1, 2 and 5, the differences observed between supplemented and unsupplemented treatments in lamb mortality to weaning were 6, 0 and 33% respectively. The lamb mortality values for the unsupplemented treatments were 14, 11 and 43% for Experiments 1, 2 and 5 respectively. Such figures based on relatively small samples of ewes are somewhat unreliable, in that bad weather conditions at lambing, or an inexperienced shepherd can distort the values obtained. An alternative approach was adopted using the frequency distribution of lamb losses in relation to birthweight class derived from the previous 6 years' data for the flock (See Fig 4.1). The differences in lamb mortality between supplemented and unsupplemented treatments using this approach were 4, 3 and 24% for Experiments 1, 2 and 5 respectively. The predicted lamb mortality values for the unsupplemented treatments were 28, 21 and 34% respectively. The higher mortality values in Experiment 5 are in part a reflection of low birthweights of twin lambs.

Since between-year differences in lamb mortality are usually high, it is not unreasonable to combine the data from the 3 experiments. Mid pregnancy supplementation which increases lamb birthweights by 9% will reduce losses to weaning by 10% in the context of the operation of a two pasture system on heather moorland at relatively high stocking rates.

In these experiments, all the ewes were grazed on intensively managed, improved species swards between lambing and weaning, with the aim of removing any carry-over effects from one experiment to another. Consequently the ewes and lambs were offered a higher level of nutrition than most systems of management would provide. However, under these circumstances there was a positive relationship between birthweight and weaning weight, as has been observed in other studies. When the data were examined for lambs born to supplemented and unsupplemented ewes (in mid pregnancy), for each

0.1 kg increase in birthweight, there was an increase of 0.19 ($p<0.001$), 0.13 ($p<0.05$) and 0.22 ($p<0.001$) kg in weaning weight in Experiments 1, 2 and 5 respectively. Russel, Doney and Eadie (1978) reported that a difference of 0.1 kg in birthweight resulted in a difference of 0.3 kg in weaning liveweight with two-pasture systems of production on hills covered with blanket bog vegetation.

At parturition ewes that had received mid pregnancy supplementation had higher condition scores than unsupplemented ewes, with the difference achieving statistical significance in Experiment 5. The higher condition scores at this time are likely to be associated with a higher initial milk supply (Peart, 1970) and greater overall yield (Gibb and Treacher, 1980, Peart, 1967, 1968). The high lamb mortality rates found in Experiment 5 with ewes unsupplemented in mid pregnancy may be associated with poorer initial milk supply. In these experiments, the effects of the pregnancy treatments on ewe liveweight and condition score had disappeared by weaning time, although in circumstances where nutrition from pasture during lactation may be less than in these experiments, this may not be the case and could lead to ewes having higher body condition at the following mating. There is no published evidence on the nature of such responses.

Increasing birthweight by 9% through mid pregnancy supplementation could reduce lamb mortality by 10%, increase weaning weight by approximately 1 kg and possibly increase ewe liveweight at weaning. At the present time, the cost of mid pregnancy supplementation would be economically justifiable based on the above figures.

Since this research was completed, real-time ultrasonic scanning to determine foetal number in mid pregnancy has been developed for commercial use on a farm scale (White, Russel and Fowler, 1984). This will allow the differential feeding of single and twin bearing ewes in late pregnancy. In Experiments 1, 2 and 5 all ewes were offered the same amount of supplementary feeding in late pregnancy, although in Experiment 5 the composition of the supplement was varied. If theories about the effect of mid pregnancy nutrition on placental weight are validated, then more advantage should be gained in separately feeding single and twin

bearing ewes in late pregnancy, if the ewes have been offered supplementation in mid pregnancy.

Method of supplementary feeding (Section 4.3)

One of the aims of the study was to examine the methods by which supplements were given in pregnancy in order to describe the management and nutritional implications of their use under hill conditions in a more critical way than had been done previously. In Experiment 1, no gross differences in ewe or lamb performance were noted between the use of a hand fed pellet and a self help feedblock, although there were difficulties of controlling intake to the desired level, and higher between-animal variability was found with the use of feedblocks. Such observations had been made previously (see Kendall, 1977).

When feedblocks were allocated once weekly in mid pregnancy, or once or twice weekly in late pregnancy in Experiments 2 and 5 to provide the desired level of intake, high voluntary intakes of feedblock were found when feedblocks were newly allocated, with lower intakes being observed later in the period before replacement, or in some cases zero intake, if the supply of feedblock had been exhausted. This led to high between-day variability in supplement intake. However, between-day variability in supplement intake is not only associated with availability of feedblock, since high between-day variation was found in Experiments 3 and 7, when feedblocks were offered ad libitum. Changes in weather conditions affecting herbage availability and the intake characteristics of the surface of the feedblock (Ducker and Fraser, 1975) are suggested as possible reasons. Although between-day variability in supplement intake was lower on the larger area in Experiment 6, this was considered to be due to the lower voluntary intakes and thus greater availability of feedblock rather than the effect of area size per se.

Voluntary intakes of feedblocks were affected by the composition of feedblock when a strict comparison was made in Experiment 3. The more open texture of a late pregnancy feedblock associated with its composition produced higher intakes than those from a mid pregnancy feedblock. However, in Experiment 7 differences in hardness induced by the treatment process without changing the composition of the

feedblock, had no effect on supplement intake. Within the small range of studies, urea content had no influence on feedblock intake (Experiment 5), although the inclusion of 5% white fishmeal decreased voluntary intakes in the same experiment. This contrasts with the observations of Bishop and Grobler (1971) with cattle; however, Goatcher and Church (1970a) pointed out that different species react differently to various substances.

The use of containers was found to have no effect on reducing voluntary intake. Size of area within which the feedblock is placed may have an effect on feedblock intake, but other factors such as herbage availability may be more important. Jones (1966) and Armstrong (1976) reported increases in the consumption of salt/urea blocks as the nitrogen content of the available pasture declined. There was evidence in Experiment 2 in late pregnancy, and in Experiment 7, that a greater availability of A/F reduced the voluntary intake of feedblock. However, there was no effect on voluntary intake of supplement when feedblocks were placed on either one or the other type of vegetation. Voluntary intakes of feedblock increased with time in several experiments (Experiments 2, 3 and 5 over pregnancy). The explanation may be due partly to the different types of feedblock used in mid and late pregnancy (Experiment 3), partly to familiarity (for example, non feeders starting to eat supplement (Experiment 1)), and partly to an apparent increase in appetite drive in late pregnancy (for example, the rapid increase to desired levels of intake achieved in Experiments 2 and 5 in late pregnancy by those ewes that had not received supplement in mid pregnancy).

Since voluntary intakes in these experiments were consistently higher than the desired intake, between-day variability in feedblock intake was high. Between-animal variation in supplement intake (to be discussed below) was also high, although between-day and between-animal variations were not found to be closely related. The combination of these two effects implies that feedblocks are an inefficient means of providing a supplement. However, there was no direct evidence that this would necessarily lead to a deleterious effect on animal performance when feedblocks are offered in mid pregnancy

(e.g. in Experiment 1). More critical experiments than Experiment 1 are required to test this more rigorously. In late pregnancy, there was evidence that the combination of between-day and between-animal variability in feedblock intakes had undesirable consequences. The identification of non feeders or ewes with low intakes using a marker frame as described in Experiment 5, has considerable potential for alleviating the problems associated with high variability in intake.

High coefficents of variation between animals in supplement intake were observed in Experiments 1, 2, 5, 6 and 7. There were fewer instances of non feeders in these experiments than with other studies of self help feeds (Nolan et al, 1975; Lobato and Pearce, 1980; Ducker et al, 1981). This is attributed to the early training of hoggs to eat supplements and to the exposure to feedblocks of all ewes in Experiment 1, when access of herbage was limited prior to the start of Experiment 1. Lobato, Pearce and Beilharz (1980) described the beneficial effects of preweaning exposure to molasses/urea blocks on intake from blocks in later life. This might be a useful management procedure to adopt.

Coefficients of variation between animals were not related to the type of feedblock used (Experiment 3) or siting of feedblocks (Experiments 2 and 5). There were significant rank correlations within groups of ewes in supplement intake on different occasions in Experiments 1 and 3, which indicated that if the sources of variation could be explained, then the consistency of the ranking might allow variation to be reduced. Likely causes of the variation were bearing type, age and size of ewe, teeth status and aspects of social behaviour. Teeth status was good in these experiments, and bearing type did not explain significant amounts of variation. In Experiment 7, social dominance explained 25% of the variation in intake when feedblock was offered ad libitum. It may be more important where access to feedblocks is limited. Social dominance was related to the age of the ewe, but not to liveweight per se. Two-year-old ewes tended to be low in the social dominance order, and to have low intakes. Low intakes of 2-year-old ewes were also observed in Experiments 5 and 6. These ewes have not reached maturity, and require additional nutrients for growth as well as

for placental and foetal development in pregnancy. It may be advantageous if feedblocks are to be used, for 2-year-old ewes to be wintered as a group separate from the rest of the flock. As was argued in Section 3.7.4, individual preferences for feedblock may be an important source of variability in intake, and this may be worthy of further examination.

One potential advantage of feedblock use as a management aid is that the area where ewes graze can be influenced by the siting of the feedblock. This was demonstrated in Experiments 2 and 5 by differences in plasma and rumen parameters when ewes grazed near feedblocks on heather or on A/F vegetation which was confirmed by behavioural observations. Grant and Milne (1981) pointed out that grazing and trampling of mature heather in winter could cause considerable damage. Siting of feedblocks on younger heather or A/F grassland could reduce these problems. Alternatively, placing the feedblocks on heather during early winter would reduce grazing pressure on A/F grassland and conserve fodder to provide better nutrition in late pregnancy.

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APPENDIX TABLES

APPENDIX TABLE A1

Individual ewe liveweights (kg) and condition scores recorded during Experiment 1. (M is missing value)

Ewe number	Treatment	Age (years)	Liveweight 12 Nov 79	Liveweight 4 Jan 80	Cond. score 4 Jan 80	Liveweight 29 Feb 80	Cond. score 29 Feb 80	Liveweight 11 April 80	Cond. score 11 April 80	Liveweight 22 May 80	Liveweight 18 August 80
1	A	2	53.0	48.0	3.25	47.0	2.25	49.5	2.25	49.0	45.0
2	A	2	M	50.0	3.00	48.0	2.25	46.0	2.50	M	60.0
3	A	2	M	58.5	3.50	51.5	2.25	53.5	2.25	55.0	56.0
4	A	2	52.0	48.5	3.25	43.0	2.00	43.5	2.00	48.5	44.0
5	A	2	57.0	56.0	3.00	52.0	2.25	49.5	2.25	48.0	50.5
6	A	2	53.0	47.0	3.25	45.0	2.00	46.5	2.00	47.5	53.0
7	A	2	56.0	51.5	3.25	46.0	2.25	49.5	2.50	49.0	53.0
8	A	2	60.0	54.5	3.25	48.0	2.25	50.5	2.25	54.0	60.0
9	A	2	50.0	47.5	3.00	43.0	2.25	45.5	1.50	46.0	56.0
10	A	2	45.5	53.5	3.00	45.5	2.00	49.0	1.75	M	47.0
11	A	2	54.0	47.5	3.00	41.0	2.25	37.0	1.75	44.0	51.0
12	A	2	60.0	56.0	3.00	M	M	M	M	M	M
13	A	2	M	49.5	3.25	42.0	2.25	43.0	2.00	51.0	56.0
14	A	2	60.0	57.0	3.00	45.0	2.00	48.0	2.25	56.0	55.0
15	A	2	54.0	49.5	3.00	42.0	2.25	43.0	2.50	53.0	60.0
16	A	3	55.0	52.0	3.25	46.5	2.25	48.0	2.00	47.0	52.0
17	A	3	52.0	51.0	2.75	43.0	1.75	49.5	2.00	46.0	51.0
18	A	3	64.0	57.5	3.25	52.0	2.00	54.0	2.00	55.5	58.0
19	A	3	64.0	64.0	2.50	53.0	2.00	58.0	2.25	58.0	60.0
20	A	3	54.0	51.5	3.00	44.0	2.00	48.0	2.25	47.0	51.0
21	A	3	62.0	58.0	3.00	51.5	2.25	57.5	2.25	54.0	64.0
22	A	3	67.0	61.5	3.25	58.0	2.25	63.0	2.25	52.0	65.0
23	A	3	60.0	56.5	3.00	48.0	2.25	53.5	2.00	48.0	52.0
24	A	3	66.0	61.5	3.50	54.0	2.50	52.5	2.75	61.0	M
25	A	3	63.0	54.0	3.50	52.0	2.25	55.0	2.00	52.0	51.0
26	A	3	53.0	51.5	2.25	46.0	1.50	45.0	1.75	51.0	60.0
27	A	3	49.0	48.0	3.25	44.0	2.25	50.5	2.25	45.5	48.0
28	A	3	58.0	53.0	2.75	47.0	1.75	51.5	2.00	51.0	53.0
29	A	4	47.0	51.0	2.50	45.0	1.50	49.0	1.75	46.0	50.0
30	A	4	54.0	50.0	2.75	47.0	1.75	49.5	2.00	51.0	48.0
31	A	4	62.0	62.0	2.75	54.5	2.00	62.5	2.25	59.5	60.0
32	A	4	62.0	58.5	3.00	51.0	2.00	58.0	2.25	58.0	65.0
33	A	4	58.0	67.5	3.25	58.5	2.25	66.0	2.00	59.5	58.0
34	A	4	63.0	59.0	3.50	52.5	2.00	57.0	1.75	49.5	57.0
35	A	4	63.0	60.5	3.25	53.0	2.25	55.5	2.25	52.0	66.0
36	A	4	52.0	46.5	2.50	43.0	1.75	47.5	2.00	50.0	51.0
37	A	4	68.0	63.5	3.25	58.0	2.25	62.5	2.25	52.5	58.0
38	A	4	60.0	60.5	2.75	53.0	2.00	61.0	2.00	53.0	M
39	A	4	54.0	51.5	2.50	47.5	2.00	52.5	2.00	49.0	59.0
40	A	4	64.0	59.5	3.00	52.5	2.25	58.0	1.75	52.0	56.0
41	A	5	57.5	52.0	3.00	47.0	2.00	49.0	2.00	46.5	55.0
42	A	5	67.0	64.0	3.00	57.0	2.25	61.0	2.25	55.0	64.0
43	A	5	56.0	52.0	2.75	50.0	2.25	52.5	1.75	46.0	55.0
44	A	5	59.5	57.5	3.25	45.0	2.25	53.5	2.25	50.0	56.0
45	A	5	54.5	52.0	2.75	47.0	2.00	46.0	2.00	46.0	54.0
46	A	5	61.5	58.5	3.25	52.0	2.25	55.0	2.00	54.0	50.0
47	A	5	52.0	52.5	2.00	45.5	1.50	48.0	1.50	43.0	51.0
48	A	6	55.0	52.5	2.75	44.0	1.75	50.0	1.75	43.0	49.0
49	A	6	73.5	67.5	2.75	58.5	2.25	64.5	2.25	58.0	67.0
50	A	6	51.0	54.5	2.75	53.0	2.25	56.5	2.25	48.5	48.0

Appendix table A1 cont

Ewe number	Treatment	Age (years)	Liveweight 12 Nov 79	Liveweight 4 Jan 80	Cond. score 4 Jan 80	Liveweight 29 Feb 80	Cond. score 29 Feb 80	Liveweight 11 April 80	Cond. score 11 April 80	Liveweight 22 May 80	Liveweight 18 August 80
51	C	2	58.0	56.0	3.00	55.0	2.50	53.0	2.25	53.0	51.0
52	C	2	58.0	52.5	3.00	52.0	2.25	M	M	50.0	49.0
53	C	2	M	50.0	2.50	51.0	2.25	47.5	2.25	48.5	53.0
54	C	2	61.0	51.5	3.25	55.0	2.00	53.5	2.00	54.0	56.0
55	C	2	56.0	48.0	3.00	51.0	2.75	48.0	2.25	43.0	50.0
56	C	2	55.0	51.0	2.50	53.0	1.75	53.5	1.50	51.5	53.0
57	C	2	51.0	47.5	3.00	44.0	2.50	41.5	2.00	47.0	55.0
58	C	2	61.0	60.0	3.25	58.5	2.25	59.0	2.00	59.0	55.0
59	C	2	55.0	51.0	3.50	51.0	2.50	48.5	2.50	50.0	52.0
60	C	2	60.0	59.5	2.50	55.5	2.50	56.0	2.50	56.0	67.0
61	C	2	57.5	51.5	2.75	49.5	2.25	49.0	2.50	49.5	53.0
62	C	2	56.0	55.0	3.25	54.5	2.75	53.5	2.50	53.0	53.0
63	C	2	51.0	46.5	3.00	47.0	2.25	45.5	2.25	M	54.0
64	C	2	51.0	46.5	2.75	47.0	2.25	44.5	2.25	45.0	M
65	C	3	60.0	54.5	3.00	53.5	2.50	56.5	2.50	52.0	59.0
66	C	3	58.0	53.0	3.50	53.0	2.75	52.0	2.50	47.0	49.0
67	C	3	55.0	50.5	3.00	49.5	2.25	47.5	1.75	43.5	51.0
68	C	3	58.5	55.5	3.25	56.0	2.25	58.5	2.50	M	54.0
69	C	3	49.0	49.5	1.75	49.0	1.75	51.5	2.00	50.0	57.0
70	C	3	58.0	54.5	3.00	57.0	2.25	58.5	2.00	52.0	56.0
71	C	3	51.0	47.0	2.50	48.0	2.25	47.0	2.25	44.0	54.0
72	C	3	68.0	63.0	3.50	61.5	2.25	63.0	2.50	61.0	61.0
73	C	3	53.0	50.5	3.25	51.5	2.50	50.5	2.25	43.0	46.0
74	C	3	54.0	53.0	3.00	53.0	2.50	53.0	2.25	45.5	52.0
75	C	3	56.0	55.5	3.25	56.0	2.50	56.5	2.25	53.0	58.0
76	C	3	51.0	53.0	2.75	49.0	2.25	50.0	2.00	47.0	57.0
77	C	4	45.5	41.5	2.00	38.0	1.75	31.0	1.25	35.0	41.0
78	C	4	67.0	61.5	2.75	61.0	2.25	64.5	2.00	59.0	57.0
79	C	4	52.0	53.5	3.00	53.0	2.00	M	2.25	56.0	54.0
80	C	4	60.0	56.5	2.75	55.0	2.25	57.0	2.25	51.0	55.0
81	C	4	64.0	61.5	3.25	59.0	2.25	60.0	1.50	54.0	47.0
82	C	4	59.5	60.0	3.25	54.0	2.50	56.5	2.25	48.5	58.0
83	C	4	61.0	58.0	3.00	53.5	2.25	56.0	2.25	50.0	65.0
84	C	4	61.5	56.0	2.50	63.0	2.50	62.5	2.25	55.0	59.0
85	C	4	49.0	48.5	2.25	50.5	2.25	47.0	2.00	M	M
86	C	4	51.0	46.0	2.75	M	M	M	M	M	M
87	C	4	58.0	59.5	3.25	60.5	2.25	61.0	2.25	52.5	66.0
88	C	4	56.0	55.0	3.00	53.0	2.75	51.5	2.25	50.5	57.0
89	C	5	66.0	64.0	3.25	61.0	2.75	58.5	2.75	M	71.5
90	C	5	54.0	52.5	2.25	56.5	1.75	56.5	1.75	54.5	53.0
91	C	5	61.0	56.0	2.50	56.5	2.00	57.0	1.75	52.0	M
92	C	5	66.0	61.0	2.50	54.5	2.25	55.5	1.75	50.5	61.0
93	C	5	61.5	56.5	3.25	50.5	2.25	52.0	1.75	47.5	54.0
94	C	5	51.0	48.5	2.25	48.0	2.00	45.0	1.75	44.0	47.0
95	C	5	58.0	53.0	3.00	53.0	2.25	54.5	2.00	48.0	54.0
96	C	5	62.0	58.0	2.50	59.0	1.75	57.0	2.25	53.0	65.0
97	C	6	52.0	55.0	2.25	57.0	1.50	56.0	1.50	49.0	M
98	C	6	61.5	55.0	2.50	56.5	2.25	43.5	1.75	51.0	M
99	C	6	55.0	52.5	3.00	54.0	2.50	54.5	2.50	43.0	46.0

Appendix table A1 cont

Ewe number	Treatment	Age (years)	Liveweight 12 Nov 79	Liveweight 4 Jan 80	Cond. score 4 Jan 80	Liveweight 29 Feb 80	Cond. score 29 Feb 80	Liveweight 11 April 80	Cond. score 11 April 80	Liveweight 22 May 80	Liveweight 18 August 80
100	B	2	58.0	45.5	3.25	50.0	2.25	46.0	2.25	50.0	55.0
101	B	2	51.0	50.0	3.00	46.0	2.25	45.5	2.25	47.0	52.0
102	B	2	58.0	55.0	3.00	48.5	2.25	47.5	2.00	49.0	55.0
103	B	2	60.0	53.0	3.25	47.0	2.25	46.0	2.00	54.0	56.0
104	B	2	54.0	47.5	3.00	42.0	2.25	45.5	2.25	47.0	49.0
105	B	2	56.0	49.5	3.00	46.0	2.25	42.5	1.75	49.5	55.0
106	B	2	54.0	49.5	3.00	44.0	2.00	38.5	1.75	47.0	51.0
107	B	2	60.0	54.0	3.50	42.0	2.50	47.5	2.25	47.5	56.0
108	B	2	M	54.5	3.00	47.0	2.25	47.0	2.25	36.0	M
109	B	2	55.0	50.0	3.00	48.0	2.25	46.0	2.25	46.0	50.5
110	B	2	53.0	48.0	3.25	44.0	2.25	46.0	2.00	48.0	48.0
111	B	2	53.0	46.5	3.50	44.0	2.50	44.0	2.25	M	51.0
112	B	2	60.0	56.5	3.25	48.0	2.25	50.0	2.25	45.0	53.0
113	B	3	57.0	52.0	2.25	46.0	2.00	43.0	1.25	58.0	55.0
114	B	3	54.0	55.5	2.75	44.5	1.75	46.5	2.00	50.0	59.0
115	B	3	52.0	49.5	3.00	47.0	2.25	50.0	2.25	48.0	51.0
116	B	3	54.0	61.5	3.25	49.0	2.00	53.5	2.25	55.0	56.0
117	B	3	53.0	53.5	3.00	45.0	2.25	48.0	2.25	37.0	40.0
118	B	3	56.0	50.0	3.00	50.0	2.00	49.0	2.25	52.5	55.0
119	B	3	52.0	52.5	3.25	44.0	2.50	45.0	2.25	48.0	56.0
120	B	3	63.0	58.0	3.25	49.0	2.25	57.0	2.50	53.0	51.0
121	B	3	54.0	52.0	3.00	47.0	2.25	47.0	2.25	43.5	50.0
122	B	3	56.0	52.5	2.75	47.0	2.25	51.5	2.00	52.0	51.0
123	B	3	56.0	52.5	2.75	50.0	2.00	54.5	2.25	53.0	58.0
124	B	3	59.0	50.0	2.50	42.0	2.00	44.0	2.00	44.0	51.0
125	B	3	52.0	52.5	2.50	47.0	1.75	46.5	1.75	49.0	58.0
126	B	3	54.0	51.5	2.50	47.0	2.00	46.0	2.25	45.5	51.0
127	B	4	50.0	43.0	2.00	40.0	1.50	45.0	1.50	41.0	43.0
128	B	4	57.0	53.5	3.25	51.0	2.25	54.0	2.00	47.0	47.0
129	B	4	57.0	54.0	3.25	45.0	2.25	51.5	2.00	47.0	61.0
130	B	4	62.0	59.5	3.50	52.0	2.25	52.5	2.25	M	M
131	B	4	55.5	54.0	2.75	47.0	2.25	43.5	2.25	52.0	59.0
132	B	4	57.0	54.5	2.75	49.0	2.25	54.0	2.00	47.0	50.0
133	B	4	52.0	52.0	2.50	39.0	1.50	37.0	1.75	48.0	56.0
134	B	4	56.0	55.0	2.00	49.0	2.25	49.0	1.75	47.0	53.5
135	B	4	60.0	54.5	3.25	48.5	2.00	51.0	2.00	46.0	49.0
136	B	4	58.0	55.5	3.00	48.5	2.00	57.5	2.00	43.0	54.0
137	B	4	63.0	61.5	2.50	50.5	2.25	50.0	2.75	M	68.0
138	B	4	51.0	51.5	2.75	46.0	2.00	52.0	2.00	M	M
139	B	4	66.0	61.0	3.50	53.0	2.75	51.5	2.75	58.0	62.0
140	B	5	62.5	58.5	2.75	53.0	2.00	59.0	1.75	52.0	58.0
141	B	5	79.5	74.5	3.50	62.0	2.00	71.5	1.75	60.0	63.0
142	B	5	61.0	54.5	3.00	49.0	2.25	50.5	2.00	49.0	51.0
143	B	5	63.0	61.5	2.50	53.0	2.00	59.0	2.25	53.0	M
144	B	5	60.0	60.5	2.50	50.0	1.75	55.0	1.75	53.0	58.0
145	B	5	55.0	50.5	2.75	48.0	2.00	52.0	2.25	43.0	53.0
146	B	5	60.0	58.0	3.25	50.0	2.00	56.0	1.75	55.0	59.0
147	B	6	60.5	55.0	2.75	51.0	2.25	58.5	2.00	58.0	57.0
148	B	6	57.0	52.0	2.25	46.0	2.00	49.0	2.00	49.0	52.0
149	B	6	59.0	54.0	2.75	47.0	2.00	49.0	2.00	44.5	55.0

Appendix table A1 cont

Ewe number	Treatment	Age (years)	Liveweight 12 Nov 79	Liveweight 4 Jan 80	Cond. score 4 Jan 80	Liveweight 29 Feb 80	Cond score 29 Feb 80	Liveweight 11 April 80	Cond. score 11 April 80	Liveweight 22 May 80	Liveweight 18 August 80
150	D	2	53.0	47.0	3.25	42.0	2.25	42.5	2.25	41.5	45.0
151	D	2	60.0	53.5	3.25	48.5	2.50	44.5	2.25	51.0	62.0
152	D	2	52.5	49.5	3.25	48.0	2.25	51.0	2.00	46.0	46.0
153	D	2	51.0	46.0	3.00	44.0	2.50	46.5	2.25	47.0	47.0
154	D	2	50.0	47.5	2.75	43.0	2.00	44.0	2.25	44.0	48.0
155	D	2	60.0	55.0	3.25	52.0	2.25	45.0	2.00	57.0	61.5
156	D	2	57.0	50.5	3.00	49.5	2.50	52.0	2.25	44.5	46.0
157	D	2	53.0	48.0	3.00	45.5	2.50	46.5	2.25	43.0	45.0
158	D	2	49.5	45.5	3.25	45.0	2.25	46.0	2.50	47.0	47.0
159	D	2	54.0	50.0	3.00	46.0	2.25	43.0	2.00	47.0	48.0
160	D	2	55.0	47.5	3.00	44.0	2.25	45.0	2.50	51.0	51.0
161	D	2	61.0	55.0	3.25	47.0	2.50	44.0	2.50	54.0	60.0
162	D	2	54.0	49.0	3.00	45.0	2.25	46.0	2.25	47.0	51.0
163	D	2	56.5	51.0	3.50	50.0	2.50	48.5	2.50	51.5	61.0
164	D	2	46.0	44.0	2.75	39.0	2.00	39.5	2.25	42.0	46.0
165	D	3	52.0	49.5	2.25	47.0	2.00	48.0	2.00	47.0	50.0
166	D	3	58.0	56.5	2.50	52.0	2.25	59.5	1.75	55.0	M
167	D	3	52.0	50.0	2.75	50.0	2.25	46.0	2.00	50.0	54.0
168	D	3	59.0	53.5	2.75	52.0	2.00	57.0	1.50	51.0	46.0
169	D	3	64.0	58.0	3.25	57.0	2.50	60.5	2.00	M	M
170	D	3	53.0	49.5	3.00	49.0	2.50	53.5	2.00	46.0	49.0
171	D	3	52.0	48.0	3.00	45.5	2.25	49.0	1.75	44.0	50.0
172	D	3	56.0	55.5	2.00	52.0	2.00	54.5	1.75	50.0	55.0
173	D	3	58.0	58.5	3.25	55.0	2.25	59.0	2.25	50.0	57.0
174	D	3	63.0	56.5	3.00	53.5	2.25	56.5	2.25	57.0	66.0
175	D	3	57.0	56.0	3.00	53.0	2.25	57.0	2.25	50.0	M
176	D	3	61.0	57.5	3.25	52.0	2.50	50.5	2.00	48.0	51.0
177	D	3	53.0	46.5	2.50	42.0	2.00	41.5	2.25	M	61.0
178	D	4	55.0	58.5	2.75	55.0	2.25	58.5	2.25	61.0	62.0
179	D	4	57.0	55.5	2.50	52.0	2.25	58.0	2.25	51.5	45.0
180	D	4	56.0	53.5	2.50	51.0	1.75	55.5	1.75	54.0	55.0
181	D	4	56.0	57.5	2.75	53.0	2.25	61.0	1.75	49.0	56.0
182	D	4	71.0	69.0	3.00	63.0	2.25	65.5	2.50	62.0	64.0
183	D	4	63.0	61.5	3.00	63.0	2.25	65.0	2.25	55.0	56.0
184	D	4	70.0	65.0	4.00	59.0	2.75	60.0	2.50	50.5	53.0
185	D	4	61.0	57.0	3.25	55.0	2.25	60.0	2.25	48.0	53.0
186	D	4	53.0	54.5	3.25	49.0	2.25	52.0	2.25	49.5	50.0
187	D	4	59.5	56.5	2.75	53.0	2.25	62.5	1.50	54.0	53.0
188	D	4	64.0	61.5	3.00	55.0	2.50	57.0	2.00	50.0	54.0
189	D	4	52.0	48.5	2.50	45.0	2.00	44.5	2.00	44.0	49.5
190	D	5	61.0	56.5	3.00	52.0	2.00	58.5	2.00	46.5	54.0
191	D	5	58.0	54.0	2.25	52.0	2.00	57.0	1.75	53.0	54.0
192	D	5	62.5	59.0	2.50	53.5	2.25	59.0	1.50	59.0	53.0
193	D	5	57.0	51.0	3.25	51.0	2.25	52.0	2.00	48.0	45.0
194	D	5	69.0	63.5	3.00	58.0	2.75	60.5	2.75	59.0	60.0
195	D	5	63.5	61.0	3.00	60.0	2.25	66.0	2.00	50.5	61.0
196	D	5	61.0	64.0	3.50	57.5	2.25	63.5	2.25	56.5	55.0
197	D	5	62.0	55.5	2.50	54.0	2.25	59.5	2.25	53.0	58.0
198	D	6	56.0	51.5	2.50	47.5	2.25	53.0	1.75	46.0	51.0

APPENDIX TABLE A2

The performance of lambs born to individual ewes in Experiment 1. Treatments A,B,C and D comprise ewe nos 1 to 50, 100 to 149, 51 to 99 and 150 to 198 respectively.

Treatment A: ewe nos 1 to 50

Ewe No	Date of birth	Sex	Birth weight (kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
1	19 April	M	2.6	10.5	23.0
		F	2.4	10.5	23.0
2	Barren				
3	27 April	M	2.8	10.5	
		M	2.3	6.0	21.0
4	21 April	F	2.5	11.5	25.0
5	17 April	F	2.0		
		F	2.4	9.0	
6	14 April	M	2.4	9.0	24.0
		F	2.0	7.0	17.0
7	3 May	M	2.1	9.0	27.0
8	21 April	M	3.8	13.0	32.0
9	Aborted				
10	Decomposing foetuses				
11	Barren				
12	Barren				
13	Died before lambing				
14	27 April	M	2.5	8.5	
		M	2.5	6.0	30.0
15	Barren				
16	21 April	M	3.0	10.0	
		F	3.0	10.0	29.0
17	16 April	M	4.4	15.5	
18	19 April	F	2.6	11.5	26.0
		F	2.6	13.0	29.0
19	20 April	F	4.0	14.0	34.0
		M	3.5	12.0	
20	21 April	M	4.6	15.5	30.0
21	22 April	F	5.7	16.0	32.0
22	22 April	F	3.4		
		*	3.5		
23	25 April	F	4.6	14.0	
24	Barren				
25	27 April	F	3.6	10.0	
		F	2.6	8.0	
26	20 April	F	1.3		
27	26 April	F	2.7	13.0	
		M	3.0	11.0	
28	27 April	F	4.8	10.0	
		F	2.0	6.5	
29	14 April	F	2.6	10.5	25.0
		M	2.4	9.0	
30	18 April	M	2.6	9.0	17.0
		F	2.8	10.0	26.0

Treatment A cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
31	19 April	M	3.3		
		F	3.0	10.5	30.0
32	19 April	M	3.6		
		M	3.3		
33	16 April	M	3.0	13.0	33.0
		F	3.0	13.0	32.0
34	15 April	F	2.5	14.5	
		M	2.8	11.5	
35	27 April	M	4.0	10.0	24.0
		F	3.2		
36	22 April	F	3.5	13.0	25.0
		F	3.0		
37	23 April	M	3.4		
		M	5.3	16.0	
38	27 April	M	3.7	11.5	
39	26 April	M	2.0		
40	26 April	M	4.9	14.0	
41	20 April	F	3.9	12.5	30.0
42	19 April	F	3.3	*	36.0
		F	2.7		
43	18 April	M	3.2	15.0	31.0
		F	2.6		
44	18 April	M	3.5	16.0	35.0
45	24 April	F	3.4	12.5	31.0
46	26 April	F	3.0	9.5	
		F	3.1	10.0	
47	27 April	M	4.5	14.0	37.0
48	13 April	F	2.3	13.0	31.0
		M	3.0	16.5	
49	14 April	M	3.1	16.0	33.0
50	26 April	F	3.7	10.0	27.0
		M	3.4	10.5	

Treatment C: ewe nos 51 to 99

51	18 April	F	2.5	7.0	20.0
		M	2.6	9.5	23.0
52	12 April	M	3.0	9.0	23.0
		F	2.5	14.5	
53	23 April	M	3.4	14.0	32.0
54	15 April	F	2.4	11.0	30.0
		M	3.0	12.0	29.0
55	22 April	F	3.0	8.0	22.0
		F	2.9	10.0	24.0
56	23 April	F	2.5	8.5	19.0
		F	2.7	9.5	19.0
57	Barren				
58	23 April	M	2.7	10.5	
		M	2.2	8.5	27.0
59	5 May	F	4.5	10.0	
60	Barren				

Treatment C cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
61	30 April	F	4.0	12.0	31.0
62	26 April	M	3.4	13.0	
63	Barren				
64	22 April	M	3.1	12.5	
65	19 April	M	3.5	14.0	
66	19 April	F	4.2	16.5	
67	14 April	F	3.5	15.0	
68	20 April	M	3.8		
		M	4.1		
69	22 April	M	5.0	14.0	29.0
70	15 April	F	2.3	14.0	
		F	2.3	13.5	30.0
71	24 April	F	4.0	12.5	
72	22 April	F	2.6	9.0	25.0
		M	2.8	10.5	25.0
73	25 April	F	2.8	10.0	
		F	3.4	10.0	
74	25 April	F	5.5		
75	24 April	F	4.3	13.0	31.0
76	27 April	M	4.6	12.5	31.0
77	Barren				
78	19 April	F	3.1	11.5	32.0
		F	3.3	12.5	27.0
79	*	F	*	14.0	23.0
80	18 April	F	3.0	*	27.0
		F	3.1	13.5	28.0
81	17 April	M	4.5	15.0	
		F	4.5	14.0	
82	13 April	F	5.3	19.5	31.0
83	20 April	F	4.5		
84	21 April	M	3.5	13.0	30.0
		M	3.3	11.0	26.0
85	24 April	M	5.2		
86	Died before lambing				
87	27 April	F	2.7		
		F	3.6	10.5	30.0
88	Barren				
89	16 April	M	3.2	14.0	33.0
		F	2.7	14.0	28.0
90	18 April	M	2.7	10.5	
		F	2.9	12.0	
91	20 April	M	3.4	14.0	28.0
92	20 April	M	4.5	15.0	34.0
93	7 May	M	3.4	8.0	
94	23 April	F	3.8	8.0	29.0
		M	3.7	11.0	
95	25 April	M	4.0		
96	18 April	M	3.5	12.0	29.0
		F	2.5	9.0	26.0
97	Barren				
98	23 April	F	5.0	14.0	
99	*	*	*	11.0	25.0

Treatment B: ewe nos 100 to 149

Ewe no	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
100	16 April	M	3.5	14.5	29.0
101	15 April	F	2.0	11.0	
		M	1.6		
102	18 April	F	2.1	12.0	37.0
		M	1.2		
103	20 April	F	3.1	12.5	27.0
104	22 April	M	3.5	13.0	30.0
105	17 April	F	1.4		
		F	2.0	9.0	25.0
106	Aborted				
107	24 April	F	3.4	12.0	
108	Decomposing foetus				
109	25 April	M	4.4	12.5	29.0
110	27 April	F	3.5		
		M	2.8	7.0	
111	Barren				
112	27 April	F	3.0	12.0	
113	13 April	*	0.8		
		*	1.0		
114	21 April	M	4.0	12.0	33.0
115	13 April	M	3.0	12.5	
		F	2.5	12.0	25.0
116	18 April	M	3.6	12.0	
		F	3.0	11.0	26.0
117	18 April	F	2.0	7.0	22.0
		F	2.5	8.0	21.0
118	14 April	F	2.6	10.5	26.0
		F	2.8	10.0	
119	12 April	M	2.0	12.0	26.0
120	23 April	M	4.0	10.5	24.0
		M	2.4	8.5	
121	23 April	F	4.3	*	33.0
122	24 April	M	3.5	12.0	36.0
		M	4.1	11.5	
123	23 April	F	4.5	15.0	36.0
124	27 April	F	3.2	11.0	26.0
125	*	M	*	6.0	
126	1 May	M	2.5		
127	16 April	F	1.9	10.0	
		F	1.6	*	21.0
128	20 April	F	3.0	12.0	
		M	3.2	13.0	29.0
129	20 April	M	4.6	15.5	31.0
130	17 April	F	2.7	7.0	
		F	3.4		
131	16 April	M	3.0	12.0	30.0
		M	3.4	14.0	36.0
132	Barren				
133	Barren				
134	23 April	F	5.0	14.0	
135	23 April	M	4.5	15.0	33.0

Treatment B cont

Ewe no	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
136	1 May	M	4.1	7.0	26.0
		M	4.2		
137	Barren				
138	3 May	F	5.0		
139	Barren				
140	16 April	M	3.5	13.0	30.0
		F	3.1	10.0	
141	24 April	F	4.9	15.0	34.0
142	13 April	F	2.5	10.5	29.0
		F	3.3	9.5	29.0
143	20 April	M	3.2	10.0	
		M	3.5	12.0	
144	20 April	M	3.2		
145	23 April	M	*		
146	5 May	M	3.6	7.5	21.0
		M	3.6	9.0	
147	17 April	F	3.4	11.5	
		F	3.1	11.5	25.0
148	23 April	M	3.0	10.0	25.0
		M	3.0	8.5	
149	23 April	F	5.1	13.0	

Treatment D: ewe nos 150 to 198

150	19 April	M	3.1	13.0	30.0
151	Barren				
152	21 April	F	2.6	10.5	23.0
		M	3.0	10.5	32.0
153	1 May	M	2.1	6.5	22.0
		F	3.6	8.5	22.0
154	18 April	Decomposing foetus			
155	Aborted				
156	21 April	M	3.8	14.0	29.0
157	19 April	M	2.9		
158	19 April	F	2.5	11.5	24.0
159	27 April	F	3.2	10.0	30.0
		F	2.3		
160	4 May	F	3.2	9.0	24.0
161	Barren				
162	27 April	M	4.1	13.0	
163	Barren				
164	4 May	F	3.5	9.0	26.0
165	15 April	M	2.6	12.0	28.0
		F	2.1	10.0	23.0
166	19 April	F	3.0	10.0	24.0
		M	3.6	13.0	28.0
167	Barren				
168	14 April	F	3.2	12.0	24.0
		M	3.6	10.5	

Treatment D cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 22 May 80	Live weight(kg) 18 Aug 80
169	20 April	F	3.5	7.0	19.0
		F	4.0	8.5	19.0
170	16 April	M	3.7	14.0	25.0
		M	3.6	13.0	29.0
171	25 April	M	5.3	11.5	30.0
172	23 April	M	4.0	13.5	31.0
173	28 April	M	3.9	11.5	
		F	3.5	9.0	22.0
174	23 April	F	2.4		
175	22 April	F	3.3	10.0	
		M	3.7	10.0	26.0
176	23 April	M	2.6	8.0	22.0
		F	3.5	10.0	24.0
177	Barren				
178	18 April	F	3.1		
		F	3.4	10.0	22.0
179	20 April	M	2.9		
180	17 April	M	3.4	13.5	31.0
		M	3.5	12.0	
181	17 April	*	3.3		
		M	3.4	16.0	29.0
182	20 April	M	4.5	16.0	37.0
183	16 April	F	4.0	14.0	
		M	3.4	12.0	28.0
184	16 April	M	4.6	20.0	43.0
185	27 April	M	3.5	6.5	27.0
		M	3.1	14.0	29.0
186	25 April	F	3.0	10.0	
		F	1.9	8.0	18.0
187	27 April	F	3.5	10.0	25.0
		M	3.9	11.0	31.0
188	27 April	F	3.5	12.0	
189	30 April	M	3.9	15.0	31.0
190	13 April	M	4.5	17.5	34.0
191	16 April	F	3.1	12.5	31.0
		F	3.6	11.5	30.0
192	20 April	F	3.8	12.5	28.0
		M	3.5	9.5	24.0
193	16 April	F	4.6	14.0	
194	28 April	F	4.2	12.5	32.0
195	23 April	M	4.5	10.0	30.0
		M	4.4	10.0	25.0
196	15 April	M	4.5		
		F	4.3		
197	23 April	F	2.9	10.5	26.0
		M	2.6		
198	21 April	F	2.2	11.0	30.0

* The lamb was alive, but the relevant information was not recorded.

The weights of lambs with missing tags have not been recorded here, and have not been included in any analysis of lamb growth rates. These lambs were included in the calculation of overall weaning rate, however. 0.31 of lambs had lost their tags at 18 August 1980

APPENDIX TABLE A3

Intake of supplement (g DM/ewe/day) by ewes for each sampling period in mid pregnancy for Treatments C and D in Experiment 1.

Ewe no	Period beginning 22 January	5 February	19 February	4 March
Treatment C				
93	42	33	71	117
79	63	53	79	166
80	71	95	80	197
76	60	46	48	89
68	85	50	51	136
95	3	34	26	48
Treatment D				
187	129	198	82	175
171	84	140	77	124
192	155	203	171	222
186	166	180	153	170
190	101	207	126	176
176	87	113	73	94

APPENDIX TABLE A4

Estimate of supplement intake by ewes on Treatment C, Experiment 1 on four sampling occasions in mid pregnancy (g DM/ewe/day)

Ewe No.	Sampling occasion			
	22 January	5 February	19 February	4 March
51	0	124	242	142
52	9	45	134	124
53	0	45	64	36
54	36	79	233	243
55	59	64	124	201
56	18	129	158	148
57	-	-	-	77
58	18	-	149	142
59	23	218	-	184
60	41	158	114	83
61	86	74	64	65
62	54	40	248	130
63	0	193	-	-
64	27	-	109	89
65	59	54	134	195
66	118	54	109	166
67	23	-	168	113
68	41	69	-	142
69	23	50	25	166
70	36	-	134	154
71	32	45	153	190
72	73	149	30	326
73	-	69	79	166
74	68	89	-	213
75	41	74	-	237
76	54	20	89	148
77	0	20	69	-
78	27	45	-	124
79	32	-	89	89
80	0	99	-	195
81	77	74	89	142
82	50	89	104	166
83	27	35	94	47
84	50	119	-	195
85	32	129	193	261
86	36	10	30	-
87	50	74	114	195
88	54	40	-	101
89	27	25	59	136
90	32	30	134	-
91	54	50	10	166
92	41	40	50	71
93	18	79	-	136
94	27	25	79	130
95	54	25	-	118
96	32	25	10	101
97	18	54	183	-
98	68	50	233	-
99	41	60	149	201

APPENDIX TABLE A5

Intakes of supplement (g DM/hd/day) by ewes on Treatments A, B, C and D in late pregnancy, Experiment 1.

Treatment A		Treatment B		Treatment C		Treatment D	
Ewe No	Intake	Ewe No	Intake	Ewe No	Intake	Ewe No	Intake
26	93	114	381	76	183	171	108
23	235	123	225	68	395	176	106
31	540	134	158	80	281	187	256
40	170	129	73	84	176	186	156
41	143	132	108	93	124	192	300
48	212	142	159	92	102	190	253

APPENDIX TABLE A6

Concentrations of ruminal NH_3 and total VFA, and the proportions of acetic, propionic and butyric acids during mid pregnancy, Experiment 1 (means of 6 observations)

	Treatment	Sampling occasion								
		15 Jan	21 Jan	29 Jan	5 Feb	12 Feb	19 Feb	26 Feb	4 March	
NH_3 (mM)	A	5.17	3.76	2.78	2.27	3.57	5.49	3.94	6.33	
	B	4.05	3.98	2.54	2.60	2.75	3.13	4.66	3.31	Means differ if $\bar{x}/\bar{y} > 1.458$
	C	5.21	3.61	2.31	4.56	5.10	3.06	3.71	3.11	
	D	5.28	3.41	2.60	2.97	2.76	3.89	3.83	3.78	
Total VFA (mM)	A	32.43	45.90	45.42	36.87	51.33	44.85	39.85	41.77	Ave SE
	B	42.18	52.28	42.05	42.78	42.90	45.85	39.95	47.83	
	C	61.78	51.97	52.88	45.02	54.60	50.50	44.47	54.22	4.914
	D	39.12	38.17	54.65	53.28	39.68	51.97	36.63	44.45	
Proportion acetic acid	A	0.743	0.727	0.741	0.727	0.726	0.718	0.734	0.696	
	B	0.716	0.739	0.734	0.709	0.725	0.726	0.716	0.717	0.0081
	C	0.700	0.720	0.701	0.722	0.690	0.729	0.734	0.698	
	D	0.693	0.731	0.726	0.716	0.723	0.714	0.688	0.688	
Proportion propionic acid	A	0.164	0.172	0.163	0.173	0.161	0.179	0.172	0.190	
	B	0.174	0.162	0.161	0.174	0.158	0.173	0.174	0.173	0.0066
	C	0.190	0.170	0.171	0.172	0.183	0.167	0.167	0.180	
	D	0.171	0.163	0.177	0.164	0.144	0.169	0.186	0.186	
Proportion butyric acid	A	0.092	0.101	0.096	0.100	0.113	0.103	0.094	0.114	
	B	0.110	0.099	0.105	0.117	0.117	0.101	0.110	0.110	0.0045
	C	0.110	0.111	0.129	0.107	0.127	0.104	0.099	0.121	
	D	0.136	0.106	0.097	0.121	0.133	0.117	0.126	0.126	

APPENDIX TABLE A7

Concentration of ruminal NH_3 and total VFA, and the proportion of acetic, propionic and butyric acids in late pregnancy, in Experiment 1. (Means of 6 observations.)

	Date	Treatment				
		A	B	C	D	Ave SE
NH_3 concentration (mm)	11 March	4.42	2.71	2.38	2.80	
	1 April	4.26	2.45	2.52	3.31	0.094
	8 April	4.53	2.94	2.96	3.15	
Total VFA concentration (mm)	11 March	45.7	37.2	44.5	45.1	
	1 April	47.8	40.7	43.2	44.9	2.99
	8 April	46.5	48.8	51.8	46.9	
Proportion Acetic acid	11 March	0.706	0.717	0.727	0.720	
	1 April	0.689	0.729	0.725	0.723	0.0058
	8 April	0.706	0.725	0.722	0.716	
Proportion Propionic acid	11 March	0.175	0.170	0.156	0.172	
	1 April	0.185	0.163	0.164	0.168	0.0048
	8 April	0.178	0.164	0.172	0.173	
Proportion Butyric acid	11 March	0.119	0.114	0.118	0.109	
	1 April	0.127	0.107	0.111	0.108	0.0039
	8 April	0.117	0.111	0.106	0.111	

APPENDIX TABLE A8

Concentrations of 3-OHB, NEFA, glucose and urea in plasma of ewes in mid pregnancy in Experiment 1 (means of 16 observations)

Plasma constituent	Treatment	Date of sampling									Ave SED	
		10 Jan	15 Jan	21 Jan	29 Jan	5 Feb	12 Feb	19 Feb	26 Feb	4 March	VI	H
	A	0.23	0.35	0.37	0.35	0.34	0.46	0.38	0.48	0.44		
3-OHB	B	0.34	0.41	0.37	0.38	0.29	0.51	0.35	0.48	0.36		
(mM)	C	0.26	0.32	0.36	0.36	0.31	0.38	0.38	0.55	0.44	§	§
	D	0.28	0.29	0.31	0.36	0.27	0.37	0.39	0.42	0.43		
	A	635	1099	680	716	643	1007	868	825	957		
NEFA	B	815	863	639	699	598	850	804	788	788	*	*
(mM)	C	700	911	621	514	707	516	785	918	932		
	D	671	932	856	472	687	561	810	670	627		
	A	3.33	3.21	3.22	3.19	3.06	3.22	3.11	3.12	2.80		
Glucose	B	3.38	3.12	3.14	3.34	3.08	3.12	3.12	2.79	3.39	0.135	0.114
(mM)	C	3.26	3.20	3.14	3.26	2.82	3.36	3.23	3.06	2.98		
	D	3.44	3.28	3.27	3.15	3.01	3.07	2.85	2.78	2.92		
	A	2.89	2.90	2.70	1.62	1.42	2.50	2.23	3.45	3.51		
Urea	B	1.97	2.28	2.39	1.81	1.29	1.39	2.32	2.51	2.41	0.294	0.220
(mM)	C	2.28	4.34	2.29	1.36	1.47	1.94	2.13	1.50	1.51		
	D	2.22	2.74	2.10	1.25	1.59	1.31	1.86	2.11	1.84		

Ave SED for comparing sampling occasions for the same treatment = H
Ave SED for comparing treatments and/or sampling occasions = VI

§ Two means different ($p < 0.05$) if $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is greater than 1.16 VI and 1.15 H.

* Two means different ($p < 0.05$) if $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is greater than 1.24 VI and 1.20 H.

APPENDIX TABLE A9

Mean concentrations of plasma 3-OHB, NEFA, glucose and urea for each treatment and for each sampling occasion in late pregnancy, Experiment 1 (means of 16 observations)

	Treatment	Sampling Date (1980)					Ave SED	
		11 March	18 March	25 March	1 April	8 April	VI	H
3-OHB (mM)	A	0.52	0.59	0.68	0.72	0.63		
	B	0.46	0.55	0.46	0.71	0.61		
	C	0.73	0.47	0.61	0.62	0.56	§	§
	D	0.46	0.56	0.82	0.68	0.73		
NEFA (mM)	A	892	899	887	972	1008		
	B	950	791	778	1122	1017		
	C	933	644	927	966	798	86.3	76.9
	D	792	885	948	922	1000		
Glucose (mM)	A	3.20	2.98	3.48	3.32	3.09		
	B	3.00	3.02	2.91	2.63	2.84		
	C	2.75	2.98	3.20	2.87	3.14	0.134	0.119
	D	2.55	2.58	3.19	2.64	2.58		
Urea (mM)	A	3.08	2.20	1.77	3.36	5.75		
	B	2.39	1.78	1.15	2.26	2.95		
	C	2.05	1.84	1.62	2.20	3.15	*	*
	D	1.80	2.04	1.41	1.69	3.11		

Ave SED for comparing sampling occasions within treatments = H
Ave SED for comparing treatments and/or sampling occasions = VI

§ Two means different $p < 0.05$ if $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is greater than 1.198 VI and 1.175 H

* Two means different $p < 0.05$ if $\bar{x}/\bar{y}$ (where $\bar{x} > \bar{y}$) is greater than 1.307 VI and 1.212 H.

APPENDIX TABLE A 10

Individual ewe liveweights (kg) and condition scores during Experiment 2. (M is missing value)

Ewe no.	Treatment	Age (years)	Liveweight 15 Dec 80	Cond.score 15 Dec 80	Liveweight 6 Jan 81	Liveweight 2 March 81	Cond. score 9 March 81	Liveweight 8 April 81	Cond.score 8 April 81	Liveweight 26 May 81	Liveweight 28 Aug 81
1	A	6	72.0	3.50	66.5	68.0	3.00	M	M	52.0	59.0
2	A	6	55.0	2.75	56.0	58.5	1.75	62.0	1.75	48.0	51.0
3	A	5	62.5	3.25	57.5	64.0	2.50	67.0	2.00	56.0	0.0
4	A	5	59.5	3.25	58.0	61.5	2.00	61.5	1.75	53.0	57.0
5	A	5	59.0	2.75	57.0	M	M	M	M	M	0.0
6	A	5	62.0	2.50	58.5	63.0	2.25	70.5	2.50	61.5	48.0
7	A	4	62.0	2.50	57.0	61.0	1.75	61.5	1.75	58.0	65.0
8	A	4	64.0	3.50	60.5	63.0	2.25	66.0	2.00	48.5	48.0
9	A	4	53.0	2.25	53.5	54.0	1.75	57.5	1.50	48.0	49.0
10	A	4	61.0	2.50	56.0	57.5	1.50	51.5	1.50	49.5	49.0
11	A	4	53.5	2.50	52.5	54.5	1.75	54.0	1.50	46.0	50.5
12	A	4	56.0	2.75	53.0	55.0	2.75	59.0	2.00	51.0	0.0
13	A	4	57.0	3.25	54.0	54.5	1.75	53.0	2.25	52.0	54.0
14	A	3	51.5	3.00	50.0	50.5	2.25	55.5	2.50	50.5	50.5
15	A	3	45.0	2.00	45.5	48.5	2.00	53.0	1.75	55.0	53.0
16	A	3	55.5	2.75	55.5	55.0	2.25	60.0	1.50	55.0	56.0
17	A	3	57.0	2.50	59.0	57.0	2.25	52.0	2.25	58.0	54.0
18	A	3	55.0	2.50	54.0	57.0	2.00	52.5	2.25	54.0	54.0
19	A	3	61.0	2.50	57.5	57.5	1.50	66.0	1.75	61.5	65.0
20	A	3	59.5	3.50	56.0	56.5	2.75	59.0	2.50	59.0	59.0
21	A	3	52.5	2.25	52.0	50.5	2.00	54.0	2.00	50.0	54.0
22	A	2	49.5	2.75	48.5	49.5	2.25	52.0	1.50	42.0	45.5
23	A	2	44.0	3.25	42.5	43.5	2.00	42.0	1.75	46.0	47.0
24	A	2	54.5	3.50	53.5	56.5	2.00	59.0	2.00	56.0	57.0
25	A	2	57.0	2.25	51.5	52.0	2.00	59.5	1.75	54.0	49.0
26	A	2	46.5	2.75	48.5	48.5	2.00	51.0	2.50	51.0	45.0
27	A	2	60.0	3.25	54.5	52.5	1.75	52.0	1.75	M	60.0
28	A	2	58.0	2.50	57.0	54.0	2.00	53.0	1.50	53.5	55.0
29	A	2	56.0	M	M	55.5	2.75	62.0	2.50	46.0	48.0
30	A	2	50.0	M	M	49.0	2.25	52.0	1.50	42.0	45.0

Appendix Table A 10 cont

Ewe no.	Treatment	Age (years)	Liveweight 15 Dec 80	Cond.score 15 Dec 80	Liveweight 6 Jan 81	Liveweight 2 March 81	Cond.score 9 March 81	Liveweight 8 April 81	Cond. score 8 April 81	Liveweight 26 May 81	Liveweight 28 Aug 81
31	C	6	57.0	2.25	57.0	59.0	1.75	M	M	45.0	54.0
32	C	6	68.5	3.25	66.5	66.5	2.25	59.0	2.00	48.0	61.5
33	C	6	68.0	3.50	60.0	70.5	2.25	66.0	2.00	67.0	66.0
34	C	5	62.5	3.25	58.5	60.5	2.25	62.5	1.50	52.0	55.0
35	C	5	66.5	3.25	64.5	67.0	2.00	54.5	1.50	53.5	55.0
36	C	5	61.5	2.75	59.5	54.5	2.25	53.0	1.50	57.0	57.0
37	C	5	60.5	3.00	54.0	55.5	2.25	55.0	1.75	52.0	49.0
38	C	5	54.0	2.00	51.0	50.5	2.00	49.0	2.50	51.0	52.0
39	C	5	59.0	2.50	55.5	56.0	1.75	59.5	1.50	48.5	42.0
40	C	5	63.5	3.50	59.5	58.5	2.25	57.0	2.50	60.0	56.0
41	C	5	70.0	3.50	56.0	66.5	2.75	M	M	M	0.0
42	C	4	58.0	3.00	55.5	59.0	2.50	61.0	1.50	53.5	56.0
43	C	4	48.0	2.00	50.5	54.5	1.75	58.0	1.75	35.0	40.0
44	C	4	56.0	2.75	53.5	59.0	2.25	61.5	2.25	49.0	53.0
45	C	4	64.0	3.50	60.5	64.0	2.25	53.5	1.75	57.0	57.5
46	C	4	64.5	3.25	62.5	66.5	1.75	M	M	58.0	60.0
47	C	4	63.0	2.75	58.5	63.0	2.50	67.0	2.50	56.0	58.0
48	C	4	57.0	2.50	58.0	59.5	1.75	M	M	55.0	53.0
49	C	4	53.5	2.75	51.5	55.5	2.00	46.5	2.00	47.0	57.5
50	C	4	56.5	2.50	54.0	52.0	2.00	48.0	1.75	54.0	56.0
51	C	4	53.5	2.75	53.5	51.5	2.50	55.0	2.00	49.0	57.0
52	C	3	55.0	2.25	53.5	58.5	1.75	62.0	1.75	46.0	41.0
53	C	3	52.0	2.50	52.5	57.5	1.75	62.5	1.50	53.0	53.0
54	C	3	56.5	2.00	56.5	63.0	1.75	68.0	1.75	54.0	45.0
55	C	3	64.0	3.50	61.5	65.0	2.50	70.0	2.25	55.0	58.5
56	C	3	53.0	2.50	51.5	57.5	2.00	50.5	1.75	51.0	55.5
57	C	3	54.0	2.50	52.5	56.0	2.50	61.5	2.25	57.0	56.0
58	C	3	58.0	3.25	57.5	61.5	3.00	68.0	2.50	59.5	55.0
59	C	3	56.5	2.50	55.5	57.0	2.00	61.0	2.50	60.5	62.0
60	C	3	50.5	2.50	51.5	53.5	2.25	61.5	1.50	55.5	51.0
61	C	3	47.5	2.50	50.5	52.0	2.50	52.0	2.25	50.5	51.5
62	C	3	50.0	2.50	48.5	53.5	2.00	55.5	1.75	53.5	53.0
63	C	3	63.0	2.50	61.5	62.5	2.00	66.0	2.00	62.0	57.0
64	C	3	64.0	3.00	61.5	59.5	2.50	62.0	2.50	60.5	57.0
65	C	3	58.0	3.00	58.0	60.5	2.00	62.5	1.50	51.0	53.0
66	C	2	44.0	2.50	44.5	47.5	2.00	50.0	2.00	48.0	57.0
67	C	2	50.0	3.00	48.0	51.5	2.25	56.0	2.00	53.0	47.0
68	C	2	50.0	2.75	50.0	53.0	2.50	57.0	2.00	52.0	54.0
69	C	2	50.0	3.50	48.5	51.0	2.00	52.0	1.75	48.0	51.5
70	C	2	53.5	3.25	53.0	56.5	2.75	58.5	2.25	59.0	49.0
71	C	2	52.5	2.50	53.5	56.5	2.00	57.0	1.50	51.5	54.0
72	C	2	56.0	3.25	55.5	56.5	2.50	55.0	2.25	55.0	56.0
73	C	2	46.0	2.75	43.5	45.5	2.00	44.0	1.75	47.5	47.0
74	C	2	51.5	2.75	49.0	49.5	2.00	52.5	1.50	49.0	53.0
75	C	2	49.0	2.75	47.5	50.5	2.00	48.5	1.75	47.0	54.0
76	C	2	53.0	2.50	51.5	50.5	2.00	50.5	2.00	45.0	50.5
77	C	2	45.0	2.50	43.5	43.5	2.00	44.0	1.50	40.0	44.0
78	C	2	53.5	2.50	49.5	54.5	2.00	55.5	1.50	46.0	52.0
79	C	2	45.0	2.75	41.5	46.5	1.75	45.0	1.50	41.0	44.0
80	C	2	55.0	M	M	51.5	2.25	51.0	2.25	53.0	49.0

Appendix Table A 10 cont

Ewe no.	Treatment	Age (years)	Liveweight 15 Dec 80	Cond.score 15 Dec 80	Liveweight 6 Jan 81	Liveweight 2 March 81	Cond.score 9 March 81	Liveweight 8 April 81	Cond.score 8 April 81	Liveweight 26 May 81	Liveweight 28 Aug 81
81	B	6	58.0	2.00	56.5	56.0	1.75	57.0	1.25	54.0	54.0
82	B	6	61.0	2.75	55.5	56.0	2.25	55.0	2.25	58.0	56.0
83	B	6	65.0	2.50	58.5	58.5	1.75	57.5	1.50	48.0	58.0
84	B	5	65.5	3.50	57.0	59.0	2.00	61.5	1.50	53.5	56.0
85	B	5	64.5	2.75	57.0	56.5	2.00	63.0	1.50	47.0	47.0
86	B	5	61.0	2.75	59.0	59.0	1.75	60.5	1.25	54.5	55.0
87	B	5	50.5	2.00	49.0	48.5	1.50	51.0	1.25	49.0	47.5
88	B	5	54.5	2.50	51.0	53.0	2.00	50.0	1.50	45.0	45.0
89	B	5	69.0	3.50	62.0	61.0	2.25	59.5	2.75	61.0	69.0
90	B	5	54.5	2.50	51.0	51.5	2.00	M	M	M	0.0
91	B	4	56.5	2.50	51.0	52.0	1.75	57.0	1.75	43.0	45.0
92	B	4	61.0	3.50	59.0	62.0	2.00	65.0	1.75	53.0	56.0
93	B	4	58.5	3.50	56.0	60.0	2.25	62.5	2.00	50.5	51.5
94	B	4	56.0	2.75	54.0	56.5	2.00	57.0	1.25	47.0	48.0
95	B	4	54.0	2.00	50.0	52.0	1.25	48.0	1.00	47.5	51.5
96	B	4	53.0	2.50	56.0	59.0	2.00	64.5	1.75	51.0	50.0
97	B	4	55.0	2.25	52.0	51.0	1.50	51.5	1.50	43.0	46.0
98	B	4	68.0	2.50	62.5	64.5	2.00	62.5	1.75	56.5	60.5
99	B	4	62.0	3.50	58.0	59.5	2.00	60.0	2.50	57.0	58.0
100	B	3	53.0	2.50	49.0	44.5	1.75	53.0	1.50	51.0	50.0
101	B	3	51.0	2.75	49.0	53.0	2.00	55.0	1.75	49.5	50.0
102	B	3	63.5	2.75	59.0	60.5	2.00	68.0	2.25	57.0	57.0
103	B	3	62.5	3.50	58.0	61.0	2.75	63.0	2.50	62.0	56.0
104	B	3	64.0	3.50	60.5	60.5	2.50	64.0	2.50	61.0	52.0
105	B	3	54.0	2.25	M	54.0	2.25	63.0	1.75	58.5	61.5
106	B	3	57.5	3.50	54.0	55.0	2.00	62.0	2.00	57.5	48.5
107	B	3	52.5	2.00	52.0	50.0	2.00	56.0	1.50	53.0	52.0
108	B	3	53.0	2.25	51.0	51.0	2.00	58.0	2.25	51.0	48.0
109	B	3	52.5	2.75	54.0	55.5	2.25	60.0	1.50	58.0	51.0
110	B	3	57.0	3.00	56.0	56.0	2.00	62.0	1.75	58.5	54.0
111	B	3	54.0	3.25	52.0	55.5	2.00	62.0	2.50	51.0	50.5
112	B	3	66.0	3.50	64.0	67.0	2.50	65.0	2.00	58.0	59.0
113	B	3	48.5	2.25	46.0	47.5	1.75	48.0	1.50	51.0	48.0
114	B	2	52.0	2.75	50.0	51.0	2.25	53.5	2.00	46.0	49.5
115	B	2	53.5	3.50	50.5	48.5	2.25	45.0	1.50	49.0	51.0
116	B	2	63.0	3.50	59.0	59.0	2.50	60.5	2.25	55.0	62.0
117	B	2	48.0	3.00	44.0	45.0	2.00	44.5	1.50	43.0	43.0
118	B	2	49.0	2.75	46.0	45.0	2.00	43.0	1.25	41.5	48.0
119	B	2	48.5	3.00	45.0	46.5	2.00	44.0	1.50	49.0	54.0
120	B	2	46.0	2.75	44.0	45.0	2.25	40.0	2.50	40.0	45.0
121	B	2	52.5	2.50	47.0	49.0	1.75	52.0	1.50	54.0	54.0
122	B	2	48.0	2.50	47.5	46.0	1.75	49.0	1.75	51.0	52.0
123	B	2	50.0	3.00	51.0	50.0	2.00	53.0	1.50	47.0	52.0
124	B	2	51.0	3.50	49.0	44.5	2.25	41.5	2.25	45.0	52.0
125	B	2	53.0	3.00	50.5	49.0	2.00	48.5	1.50	53.0	44.0
126	B	2	45.5	2.50	44.0	43.5	2.00	40.0	1.75	44.0	53.0
127	B	2	M	2.75	57.0	55.0	2.00	53.0	2.50	56.0	63.0
128	B	5	M	M	49.0	47.0	2.00	49.0	1.50	51.0	0.0
129	B	5	56.0	3.00	48.0	46.0	2.25	45.5	1.75	45.0	48.0

Appendix Table A 10 cont

Ewe no.	Treatment	Age (years)	Liveweight 15 Dec 80	Cond.score 15 Dec 80	Liveweight 6 Jan 81	Liveweight 2 March 81	Cond.score 9 March 81	Liveweight 8 April 81	Cond.score 8 April 81	Liveweight 26 May 81	Liveweight 28 Aug 81
130	D	6	65.0	2.75	60.0	61.0	2.50	67.0	2.50	61.0	53.0
131	D	6	61.5	2.50	61.0	59.5	1.75	64.0	1.75	56.0	59.0
132	D	6	52.5	2.50	52.0	49.0	2.00	49.0	1.75	45.0	53.0
133	D	5	63.5	3.00	61.0	67.0	2.00	69.0	1.50	48.5	55.0
134	D	5	59.0	2.50	M	56.0	1.75	56.0	2.00	50.5	56.0
135	D	5	68.0	2.50	61.0	71.0	2.25	71.0	1.50	53.0	57.0
136	D	5	63.0	2.50	61.0	62.0	2.00	66.5	1.00	54.0	60.0
137	D	5	53.0	2.00	57.0	53.5	1.75	49.0	1.25	39.0	0.0
138	D	5	63.0	3.50	59.0	63.0	2.25	62.5	2.50	59.0	58.0
139	D	5	61.5	3.25	60.5	60.0	2.25	62.5	1.75	51.0	53.0
140	D	5	M	2.75	52.5	63.5	2.25	65.0	1.50	50.0	0.0
141	D	4	52.5	2.75	48.0	50.5	2.25	51.0	2.25	48.0	54.0
142	D	4	57.5	2.00	55.5	M	M	M	M	M	51.0
143	D	4	63.5	2.75	61.0	62.0	2.00	64.0	2.50	50.0	53.0
144	D	4	53.5	2.50	50.5	49.0	1.75	54.0	1.75	46.0	47.5
145	D	4	50.0	2.50	50.0	49.0	2.25	57.5	2.25	46.0	41.0
146	D	4	60.0	3.25	58.0	64.5	1.75	62.5	1.75	50.0	49.0
147	D	4	54.0	3.25	54.0	56.0	2.25	56.0	1.75	44.5	0.0
148	D	4	62.5	2.75	61.0	59.5	2.50	58.5	1.50	42.0	45.0
149	D	4	59.0	2.75	53.0	56.0	1.75	59.0	1.25	51.0	53.0
150	D	4	59.0	2.75	57.0	57.0	2.25	59.0	1.50	50.0	52.0
151	D	4	61.5	2.75	56.5	52.5	1.75	55.0	1.50	52.0	55.5
152	D	3	49.5	2.75	50.0	54.5	2.25	59.0	2.50	53.0	52.0
153	D	3	52.0	2.75	52.0	55.0	2.50	56.0	2.00	53.5	0.0
154	D	3	57.5	2.25	57.0	61.0	2.00	63.5	1.75	53.0	50.0
155	D	3	72.0	3.25	72.0	71.0	2.25	78.0	3.00	71.0	56.0
156	D	3	53.5	2.50	51.0	56.0	2.00	60.0	2.00	58.0	58.0
157	D	3	61.5	2.75	55.0	58.0	1.75	59.0	1.50	53.0	58.0
158	D	3	53.5	2.50	51.0	54.0	2.25	55.0	1.50	51.0	51.0
159	D	3	52.5	2.75	53.0	59.0	2.75	60.0	2.00	53.0	48.0
160	D	3	63.5	3.25	63.0	64.5	2.50	69.0	2.25	63.0	0.0
161	D	3	54.5	2.75	54.5	55.0	2.25	56.0	1.50	55.5	55.0
162	D	3	47.0	2.50	47.5	47.5	1.75	48.0	2.00	48.5	56.5
163	D	3	59.0	3.50	56.0	59.0	2.50	61.5	2.25	58.0	58.0
164	D	3	60.0	3.50	56.0	61.0	2.25	64.0	2.50	52.0	53.0
165	D	2	55.5	3.50	54.0	56.0	2.50	57.0	1.50	54.0	59.0
166	D	2	52.5	2.25	50.0	51.0	2.00	52.0	1.75	48.0	56.0
167	D	2	48.0	3.50	45.0	49.0	2.50	50.5	2.25	43.0	46.0
168	D	2	43.5	2.50	45.0	44.0	2.00	46.0	1.50	41.0	44.0
169	D	2	52.0	3.00	53.0	55.0	2.00	M	M	42.5	48.0
170	D	2	54.0	3.50	54.0	54.0	2.25	50.0	2.00	53.0	53.0
171	D	2	50.0	3.25	47.0	47.0	1.75	49.0	1.75	44.0	48.0
172	D	2	50.0	2.75	49.0	48.0	2.50	M	M	44.0	45.0
173	D	2	49.0	3.00	47.0	46.0	2.50	47.0	1.50	42.0	47.0
174	D	2	48.0	2.50	48.0	46.0	2.00	47.0	1.75	49.5	51.0
175	D	2	44.0	3.00	44.0	44.0	2.00	44.0	1.50	42.0	41.0
176	D	2	56.0	3.00	56.0	54.0	2.25	56.0	2.25	54.5	51.0
177	D	2	49.0	3.00	49.0	52.0	2.00	53.0	1.25	44.0	50.5
178	D	2	49.0	2.75	47.0	47.0	2.25	44.0	2.25	45.0	44.0
179	D	2	50.0	3.00	57.0	51.0	1.75	50.0	1.50	54.0	48.0

APPENDIX TABLE A11

The performance of lambs born to individual ewes in Experiment 2. Treatments A,B,C and D comprise ewe nos 1 to 30, 81 to 129, 31 to 80 and 130 to 179 respectively.

Treatment A: ewe nos 1 to 30

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
1	9 April	F	1.8		
		M	2.3		
2	11 April	M	2.7	14.5	
		M	3.1	17.0	34.5
3	17 April	M	3.4		
		M	4.0		
4	12 April	M	4.5	19.5	37.0
5	Died before lambing				
6	8 May	M	4.5	8.5	21.0
		F	3.2	6.0	19.0
7	15 April	M	2.5		
		F	2.2		
8	14 April	F	3.1	11.0	24.5
		F	3.4	14.5	24.0
9	17 April	M	3.9	10.0	25.0
		F	3.6	11.0	26.0
10	Barren				
11	26 April	F	4.0	11.0	28.0
12	26 April	F	4.0	12.5	
		F	2.9		
13	Barren				
14	24 April	F	3.5	11.5	29.0
15	18 April	M	4.4	13.0	26.0
16	15 April	F	4.3	15.0	27.0
17	Aborted				
18	Barren				
19	23 April	M	4.2	12.0	
20	22 April	F	3.7	13.0	30.5
21	24 April	F	3.8		
22	16 April	M	5.1		
23	Barren				
24	20 April	F	4.2	13.5	31.5
25	28 April	F	4.5	12.0	31.5
26	24 April	F	3.7	10.0	22.5
27	Barren				
28	9 April	M	2.3	15.5	
		F	2.6	12.5	30.0
29	22 April	M	4.6	13.0	27.5
		F	4.0	11.5	29.0
30	22 April	F	3.9	11.0	33.5
		F	3.1		

Treatment C: ewe nos 31 to 80

Ewe No	Date of birth	Sex	Birth weight (kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
31	Aborted				
32	Aborted				
33	24 April	M	4.4	14.0	36.5
34	30 April	F	3.2	5.0	
		F	4.7	8.0	
35	13 April	M	3.6	14.0	28.0
		F	3.7	14.0	
36	Barren				
37	9 April	M	2.3		
		F	2.3		
38	Barren				
39	15 April	M	3.8	10.0	22.0
		F	3.5	9.5	23.0
40	Barren				
41	Died before lambing				
42	13 April	F	3.4	14.0	35.0
43	13 April	F	3.2	11.0	21.0
		F	2.9	10.0	
44	14 April	F	4.0	11.0	26.5
		M	4.0	10.0	20.5
45	Aborted				
46	8 April	M	3.0	17.5	36.5
		F	3.3	15.0	34.0
47	20 April	M	5.0	19.0	36.5
48	8 April	F	2.5	13.0	
		*	1.0		
49	Barren				
50	Barren				
51	12 April	M	2.1	10.0	
		M	2.6		
52	16 April	F	3.4	12.0	20.0
		F	3.3	10.5	23.5
53	16 April	F	2.9	9.5	24.5
		M	4.5	14.0	28.0
54	17 April	F	3.5	12.5	25.0
		M	3.9	14.0	25.0
55	14 April	M	3.5	16.0	36.0
		F	3.4		
56	Aborted				
57	21 April	M	4.5		
58	18 April	M	3.6	12.0	19.5
		F	2.9	12.0	26.0
59	19 April	F	4.4	14.5	34.0
60	20 April	F	4.3	15.0	
61	26 April	M	4.0	13.0	26.5
62	25 April	F	3.4	10.0	27.5
		M	3.5	8.5	22.0
63	21 April	M	3.6	14.0	33.0
64	21 April	M	3.6	13.0	36.0

Treatment C cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
65	15 April	F	3.9	13.0	31.5
		M	3.3	10.0	27.0
66	15 April	F	4.1	8.0	19.5
67	12 April	M	4.5	17.0	30.0
68	13 April	F	4.1	*	24.5
69	9 April	M	3.3		
70	22 April	F	3.5	11.0	17.0
		M	3.0	9.0	22.0
71	25 April	M	4.5	11.0	29.0
72	14 April	M	2.3		
73	24 April	F	3.4	12.0	
74	20 April	F	2.4	*	
		M	3.1	14.0	
75	Decomposing foetuses				
76	2 May	F	3.9	*	
77	Barren				
78	26 April	M	3.0		
		F	2.0		
79	22 April	M	4.0	13.0	28.5
80	Barren				

Treatment B: ewe nos 81 to 129

81	20 April	F	4.5	13.0	28.0
82	Barren				
83	2 May	M	3.9	11.0	30.5
84	19 April	M	2.7	*	
		M	4.0	6.5	
85	16 April	M	3.5	10.0	24.0
		F	4.0	11.5	
86	20 April	F	3.9	14.5	
		F	3.6	14.0	33.0
87	26 April	M	4.6	12.0	25.5
88	26 April	F	3.3	11.0	28.0
89	Barren				
90	Died before lambing				
91	15 April	M	3.5	13.0	29.5
		F	2.5	11.0	26.0
92	20 April	F	4.0	12.0	22.5
		M	4.0	10.0	27.0
93	20 April	F	3.6	11.0	26.0
		F	4.0	14.0	
94	14 April	F	3.9	17.0	33.5
95	14 April	F	3.4	13.0	27.5
96	17 April	M	3.4	12.5	26.0
		M	4.3	13.0	29.5
97	15 April	M	3.1	9.5	22.5
		M	2.6	8.5	21.5
98	16 April	M	3.1		
99	20 April	F	3.6	14.0	30.5

Treatment B cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
100	24 April	F	4.1	13.0	27.0
101	19 April	M	3.4	11.5	25.0
		M	3.3	13.0	24.5
102	19 April	M	3.4	12.0	
		F	3.3	12.0	27.5
103	20 April	F	3.0	8.5	29.0
		M	3.9	11.0	25.0
104	14 April	M	4.4	19.0	27.0
105	18 April	F	3.2	7.5	16.5
		F	3.4	9.5	22.5
106	22 April	F	3.0	10.5	
		F	3.5	12.0	
107	19 April	F	3.0	7.0	17.5
		M	4.0	10.5	25.0
108	21 April	F	3.2	12.0	26.5
109	23 April	F	3.2	12.0	
		F	3.9	9.5	
110	25 April	F	3.4	10.0	21.0
		M	2.6		
111	19 April	F	3.6	11.0	25.0
		M	3.6	11.0	
112	9 April	F	2.0		
		M	1.8		
113	22 April	F	3.4	11.5	24.0
114	24 April	M	3.3	12.5	33.5
115	24 April	M	2.7	10.0	28.5
		F	2.5	11.0	29.5
116	12 April	M	4.5	17.0	35.0
117	21 April	F	3.0	11.0	28.5
		F	2.0	*	
118	20 April	M	3.9	14.0	38.5
119	22 April	F	2.4	8.0	24.0
120	16 April	F	1.9	9.5	25.0
121	20 April	F	2.0	8.5	25.0
122	26 April	F	3.1		
123	11 April	M	2.6		
		F	1.8		
124	Barren				
125	30 April	F	4.4	11.0	23.0
126	Barren				
127	Barren				
128	25 April	M	4.2	14.0	30.0
129	28 April	M	4.2	12.5	27.0

Treatment D: ewe nos 130 to 179

130	25 April	F	4.3	14.5	32.5
131	23 April	M	4.8	9.0	
		M	4.3	11.0	
132	24 April	F	4.0	13.0	28.0
		F	3.2		

Treatment D cont

Ewe No	Date of birth	Sex	Birth weight (kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
133	12 April	M	3.8	16.0	35.0
		M	3.9	*	
134	21 April	M	4.9	17.0	34.0
135	12 April	F	2.6	12.0	28.0
		M	3.5	13.0	29.0
136	19 April	F	3.3	14.0	
137	22 April	F	3.3	10.0	25.5
138	23 April	F	4.1	13.5	30.0
139	21 April	F	3.1		
140	16 April	F	3.3	12.5	25.5
		M	4.1	13.0	26.0
141	29 April	F	4.2	11.0	31.0
142	Died before lambing				
143	13 April	F	3.5	14.0	
		M	3.4	14.5	24.0
144	19 April	M	4.2	17.0	33.0
145	18 April	M	3.0	13.0	26.0
		M	4.3	13.0	27.5
146	14 April	M	2.6	13.0	25.5
		M	2.6	10.5	24.0
147	17 April	M	4.3	18.0	37.5
		F	4.3	13.5	31.0
148	24 April	F	3.5	10.0	26.0
		F	3.4	9.0	26.0
149	21 April	F	3.2	11.0	27.0
		F	3.0	10.0	25.0
150	25 April	M	4.0	11.0	28.0
		M	3.6	14.5	
151	25 April	F	3.4		
152	13 April	M	3.9	17.0	26.0
153	25 April	M	4.2	13.5	30.5
154	12 April	M	3.7	15.5	28.5
155	17 April	M	5.0	20.0	30.0
156	21 April	M	4.1	16.0	30.5
157	19 April	M	3.6	10.0	
		M	3.1	10.0	22.5
158	29 April	M	4.2	11.0	28.5
159	19 April	M	2.6	11.0	23.0
		F	3.6	11.0	26.0
160	24 April	M	4.1	13.5	29.5
161	22 April	M	4.0	14.0	29.5
162	Decomposing foetus				
163	22 April	M	3.2	12.0	26.0
164	Decomposing foetuses				
165	Decomposing foetus				
166	25 April	M	3.0		
167	16 April	M	4.3	18.0	35.0
168	18 April	M	4.6	10.0	22.5
169	8 April	F	2.8	15.0	
		M	2.0	16.5	34.0

Treatment D cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 26 May 81	Live weight(kg) 28 Aug 81
170	Barren				
171	22 April	F	3.2	11.0	
172	26 April	M	4.2	12.0	25.0
173	25 April	M	4.5	15.0	34.5
174	4 May	M	4.0	9.0	28.0
175	1 May	M	3.0	7.0	20.5
		M	2.5	6.5	22.5
176	8 May	F	5.0	10.5	29.0
177	15 April	M	2.9	12.0	25.5
		F	1.9		
178	18 April	M	3.5	15.0	27.5
179	17 April	M	4.5	14.0	29.0

* The lamb was alive but the relevant information was not recorded.

The weights of lambs with missing tags have not been recorded here, and have not been included in any analysis of lamb growth rates. These lambs were included in the calculation of overall weaning rate, however. 0.18 of lambs had lost their tags at 28 August 81.

APPENDIX TABLE A 12

Intake of supplement by ewes in mid pregnancy (g DM/ewe/day) on Treatments C and D, Experiment 2.

Ewe No.	Sampling occasion: 28 Jan to 1 Feb	Sampling occasion: 27 Feb to 3 March
Treatment C		
41	94	92
34	70	106
42	122	296
46	97	163
48	294	138
51	68	168
53	127	226
56	255	454
65	114	149
63	64	220
Treatment D		
132	46	*128
141	206	157
142	216	§125
143	26	-
150	115	190
147	234	295
153	107	184
164	150	225
157	125	142
161	155	151

* Ewe No. 136 substituted for No. 132

§ Ewe No. 133 substituted for No. 142

APPENDIX TABLE A 13

Concentrations of ruminal NH_3 and total VFA, and the proportions of acetic, propionic and butyric acids during mid pregnancy, Experiment 2 (unadjusted means of 8 observations).

		Sampling occasion										
	Treatment	23 Dec	29 Dec	5 Jan	12 Jan	26 Jan	2 Feb	9 Feb	16 Feb	23 Feb	2 Mar	Ave SE
NH_3 (mM)	A	4.38	3.84	3.45	1.86	4.04	2.32	3.65	4.22	2.49	4.03	
	C	3.56	3.23	2.47	2.09	3.82	4.39	2.49	3.04	1.07	1.24	0.481
	B	6.39	3.84	3.20	1.03	3.77	2.34	3.81	4.25	2.62	1.62	
	D	3.25	3.18	2.49	1.27	1.86	2.06	3.84	4.44	2.22	1.80	
Total VFA (mM)	A	45.04	42.32	47.85	46.93	40.47	45.57	47.81	36.51	48.86	46.74	
	C	47.63	51.62	47.85	54.56	53.88	57.73	47.06	44.22	59.21	56.13	3.392
	B	43.86	50.08	41.09	49.05	43.90	47.50	47.11	36.89	42.66	43.98	
	D	53.88	51.74	48.54	48.37	48.24	52.49	54.67	56.65	49.15	36.24	
Proportion of acetic acid	A	0.767	0.739	0.755	0.805	0.730	0.761	0.763	0.735	0.780	0.746	
	C	0.769	0.774	0.762	0.786	0.720	0.737	0.748	0.689	0.760	0.771	0.0094
	B	0.755	0.731	0.775	0.790	0.722	0.721	0.755	0.695	0.770	0.775	
	D	0.773	0.748	0.787	0.807	0.752	0.744	0.726	0.715	0.729	0.739	
Proportion of propionic acid	A	0.151	0.171	0.149	0.146	0.175	0.148	0.148	0.172	0.132	0.166	
	C	0.149	0.144	0.149	0.162	0.163	0.165	0.155	0.201	0.145	0.150	0.0071
	B	0.156	0.164	0.140	0.152	0.146	0.174	0.149	0.196	0.152	0.149	
	D	0.142	0.145	0.149	0.137	0.134	0.143	0.163	0.170	0.150	0.155	
Proportion of butyric acid	A	0.082	0.090	0.095	0.050	0.095	0.092	0.088	0.094	0.088	0.088	
	C	0.082	0.082	0.089	0.053	0.116	0.098	0.097	0.109	0.095	0.079	0.0058
	B	0.089	0.105	0.085	0.057	0.132	0.105	0.096	0.109	0.079	0.077	
	D	0.085	0.108	0.064	0.056	0.114	0.112	0.110	0.115	0.120	0.106	

APPENDIX TABLE A 14

Ruminal fluid concentrations of NH_3, total VFA, and the proportion of acetic, propionic and butyric acids in late pregnancy, Experiment 2 (means of 8 observations).

	Treatment	Sampling date						
		9 March	16 March	22 March	30 March	6 April	Ave SED VI	H
Concentration NH_3 (mM)	A	3.89	3.83	3.93	4.35	7.16	0.806	0.841
	B	2.60	5.94	3.28	3.87	3.51		
	C	1.18	1.86	3.42	4.66	3.64		
	D	3.51	2.69	2.33	6.09	3.37		
Total VFA concentration (mM)	A	57.76	50.55	50.20	51.61	52.70	3.572	2.909
	B	56.44	48.50	44.78	41.21	33.05		
	C	57.68	46.89	49.50	53.52	44.24		
	D	55.39	44.23	45.75	44.86	39.40		
Proportion acetic acid	A	0.762	0.751	0.718	0.703	0.704	0.014	0.013
	B	0.700	0.726	0.738	0.740	0.764		
	C	0.716	0.735	0.723	0.731	0.735		
	D	0.730	0.728	0.757	0.725	0.717		
Proportion propionic acid	A	0.147	0.148	0.172	0.174	0.177	0.010	0.008
	B	0.170	0.175	0.161	0.165	0.127		
	C	0.166	0.169	0.177	0.172	0.159		
	D	0.161	0.155	0.144	0.169	0.165		
Proportion butyric acid	A	0.091	0.100	0.110	0.123	0.119	0.008	0.009
	B	0.131	0.099	0.101	0.095	0.110		
	C	0.118	0.097	0.100	0.097	0.106		
	D	0.109	0.117	0.099	0.107	0.118		

Ave SED for comparing weeks for the same treatment = H

Ave SED for comparing treatments and/or weeks = VI

APPENDIX TABLE A 15

Concentrations of 3-OHB, NEFA, glucose and urea in plasma of ewes in mid pregnancy in Experiment 2 (unadjusted means of 16 observations)

		Sampling occasion											
	Treatment	22 Dec	29 Dec	5 Jan	12 Jan	20 Jan	26 Jan	2 Feb	9 Feb	16 Feb	23 Feb	2 Mar	Ave SE
3-OHB (mM)	A	0.23	0.44	0.35	0.24	0.32	0.33	0.41	0.31	0.36	0.37	0.29	
	B	0.27	0.35	0.37	0.30	0.34	0.34	0.35	0.37	0.39	0.34	0.41	0.028
	C	0.30	0.38	0.36	0.28	0.36	0.42	0.64	0.45	0.50	0.46	0.76	
	D	0.35	0.28	0.26	0.30	0.34	0.39	0.50	0.40	0.42	0.50	0.42	
NEFA (mM)	A	522	727	856	556	985	630	849	595	628	969	460	
	B	494	631	997	604	947	757	670	887	554	596	626	62.3
	C	816	758	777	641	1050	792	842	917	491	585	819	
	D	562	612	604	586	945	594	711	847	647	477	635	
Glucose (mM)	A	3.27	3.11	2.98	3.18	3.25	3.39	3.17	3.69	3.08	2.79	3.04	
	B	3.11	3.06	3.16	2.97	3.10	2.93	2.75	3.19	3.21	2.98	2.94	0.093
	C	3.49	3.41	3.21	3.38	3.03	3.13	3.00	3.11	3.40	2.98	3.09	
	D	3.04	3.40	3.33	3.09	3.04	2.97	3.16	3.62	3.65	3.18	3.22	
Urea (mM)	A	4.38	3.82	2.89	1.30	0.88	2.51	3.31	3.26	3.07	2.56	2.07	
	B	2.73	2.64	1.94	0.79	0.69	1.43	2.11	2.63	2.54	1.74	1.18	0.200
	C	2.99	2.34	2.07	1.50	1.01	1.89	1.91	1.91	1.54	0.95	1.23	
	D	2.49	3.22	1.50	1.16	0.80	1.12	1.50	2.99	2.44	1.11	1.66	

APPENDIX TABLE A 16

Concentrations of plasma urea, 3-OHB, NEFA and glucose in late pregnancy, Experiment 2 (means of 16 observations).

	Treatment	Sampling date					Ave SED	
		9 March	16 March	24 March	30 March	6 April	VI	H
3-OHB (mM)	A	0.34	0.59	0.52	0.70	0.57		
	B	0.42	0.54	0.61	0.63	0.81		
	C	0.45	0.42	0.53	0.64	1.03	*1.32	*1.23
	D	0.35	0.68	0.60	0.53	0.74		
NEFA (mM)	A	643	743	799	693	872		
	B	639	649	1352	787	1160	121.6	101.3
	C	644	786	1141	955	1246		
	D	485	682	1057	707	1409		
Glucose (mM)	A	2.99	3.22	3.32	3.36	3.43		
	B	2.83	2.80	3.30	3.43	3.02	0.157	0.138
	C	3.00	2.99	3.44	3.69	3.12		
	D	3.06	3.20	3.08	3.21	3.55		
Urea (mM)	A	2.25	2.10	3.05	3.97	4.64		
	B	1.13	1.60	1.72	2.86	3.22	0.361	0.279
	C	1.05	1.49	1.74	2.41	3.28		
	D	0.98	1.22	1.51	2.07	2.91		

Ave SED for comparing sampling occasions within Treatment = H
Ave SED for comparing treatments and/or sampling occasions = VI

* Two means different ($p<0.05$) if $\bar{x}/\bar{y}$ (where $\bar{x}>\bar{y}$) is greater than stated value.

APPENDIX TABLE A 17

Intakes of DM of supplement (g DM/day) by ewes in Experiment 3.

	Period			
	1	2	3	4
Group A				
Ewe No.				
74	66	155	267	234
86	461	430	548	450
5	162	274	290	230
31	470	370	635	560
64	177	294	553	370
8117	303	223	396	135
8132	275	249	363	334
7143	162	199	489	280
7145	286	264	601	399
6124	194	177	279	240
Group B				
Ewe No.				
65	109	333	363	389
6155	12	243	351	336
12	122	211	266	353
43	191	260	280	287
7152	40	61	198	380
8128	68	420	298	427
8150	223	270	292	359
8107	60	347	313	218
7111	15	35	224	219
7155	111	222	200	215

APPENDIX TABLE A 18

Individual ewe liveweights (kg) and condition scores recorded during Experiment 5. M is missing value.

Ewe no.	Treatment	Age(yrs)	Liveweight 16 Nov 81	Liveweight 21 Jan 82	Cond.score 21 Jan 82	Liveweight 1 Mar 82	Cond.score 1 Mar 82	Liveweight 8 April 82	Cond.score 8 April 82	Liveweight 20 May 82	Liveweight 13 Aug 82
1	LE	2	55.0	47.5	2.50	44.5	2.00	49.0	1.75	56.0	59.0
2	LE	2	54.0	48.0	2.50	44.0	1.75	40.0	1.75	47.0	52.5
3	LE	2	43.5	42.0	2.75	37.0	2.00	41.5	2.25	47.0	42.0
4	LE	2	50.0	43.0	3.00	38.5	2.25	42.5	2.25	M	0.0
5	LE	2	53.5	47.5	2.50	39.5	2.00	45.0	1.50	52.0	64.5
6	LE	2	41.0	39.0	2.25	31.5	1.25	38.0	1.25	46.0	53.5
7	LE	2	48.0	42.5	2.50	37.5	2.00	42.0	1.75	48.5	56.0
8	LE	2	56.0	49.0	2.75	44.5	2.50	50.0	1.75	60.0	59.0
9	LE	2	43.0	38.0	2.50	35.0	2.25	39.0	1.75	44.0	43.0
10	LE	2	47.5	42.0	3.00	36.0	2.00	42.5	2.00	50.5	47.0
11	LE	3	51.5	45.0	2.00	42.0	1.50	47.0	1.50	55.0	55.0
12	LE	3	57.0	50.0	2.25	39.5	1.75	49.0	1.50	54.0	54.5
13	LE	3	69.0	60.5	2.50	57.0	2.25	62.0	1.75	61.0	59.0
14	LE	3	54.0	48.0	2.50	41.5	2.00	47.5	1.50	52.5	51.0
15	LE	3	58.0	54.0	2.50	49.5	1.75	57.0	1.50	59.0	53.5
16	LE	3	53.0	49.0	2.50	42.0	1.50	40.0	1.50	52.0	59.0
17	LE	3	60.5	58.0	2.00	51.0	1.50	53.5	1.25	59.0	49.5
18	LE	3	53.0	47.0	2.50	46.5	2.50	50.0	2.25	55.0	57.0
19	LE	3	56.0	51.5	2.25	42.5	1.50	49.0	1.25	61.0	60.0
20	LE	3	60.0	54.5	2.25	46.0	1.50	51.0	1.75	63.5	63.0
21	LE	4	61.0	55.0	2.50	52.0	2.00	55.5	2.00	59.0	53.0
22	LE	4	53.5	49.5	2.50	40.5	2.00	40.0	1.50	49.0	54.5
23	LE	4	61.0	57.0	2.25	51.5	1.50	54.0	1.50	55.5	63.5
24	LE	4	62.5	55.5	2.50	49.0	1.75	50.5	2.00	M	60.5
25	LE	4	57.5	54.0	2.50	52.5	2.25	53.0	2.25	57.0	55.0
26	LE	4	59.0	53.0	2.50	48.5	2.00	52.5	1.75	61.0	64.5
27	LE	4	58.0	50.0	2.00	45.0	1.50	53.0	1.00	59.0	57.0
28	LE	4	60.0	58.5	2.50	50.5	1.50	56.0	1.75	56.0	60.0
29	LE	4	63.0	59.5	2.75	53.0	2.00	59.0	2.25	M	59.0
30	LE	4	63.0	58.0	3.00	53.0	2.25	60.5	1.75	59.5	62.0
31	LE	5	62.0	56.5	2.50	51.5	1.75	57.0	1.75	54.0	55.0
32	LE	5	58.5	52.0	2.50	47.0	1.75	55.0	1.50	53.0	51.5
33	LE	5	64.0	55.0	2.50	51.5	2.00	56.5	1.50	59.5	51.0
34	LE	5	54.0	48.5	2.25	42.0	1.50	47.0	1.50	M	0.0
35	LE	5	55.0	50.0	2.50	43.0	1.50	46.5	1.50	53.0	53.0
36	LE	5	60.0	53.0	2.50	44.5	2.00	43.5	1.50	50.0	59.0
37	LE	5	59.0	58.0	2.50	50.5	1.75	57.0	1.75	59.0	58.5

Appendix table A 18 cont

Ewe no.	Treatment	Age(yrs)	Liveweight 16 Nov 82	Liveweight 21 Jan 82	Cond.score 21 Jan 82	Liveweight 1 March 82	Cond.score 1 March 82	Liveweight 8 April 82	Cond.score 8 April 82	Liveweight 20 May 82	Liveweight 13 Aug 82
38	LP	2	41.5	35.5	2.25	32.0	1.50	33.5	1.00	44.0	54.0
39	LP	2	50.5	47.0	2.25	39.0	1.50	44.5	1.00	49.0	58.5
40	LP	2	46.0	42.0	3.00	35.0	2.25	42.5	2.25	45.0	56.5
41	LP	2	49.0	43.0	2.75	37.5	2.25	45.0	1.50	49.0	52.5
42	LP	2	53.5	46.0	2.50	38.0	1.50	41.0	1.50	M	57.0
43	LP	2	46.0	41.0	2.50	35.0	1.75	35.0	1.75	48.5	58.5
44	LP	2	50.0	44.5	2.50	36.0	1.50	35.5	0.75	44.0	52.0
45	LP	2	46.0	42.5	2.50	35.5	1.75	42.0	2.00	51.0	54.0
46	LP	2	51.0	48.0	2.50	38.0	2.00	42.5	1.50	48.0	49.0
47	LP	2	51.5	48.0	2.50	43.0	2.00	45.0	1.00	49.0	49.0
48	LP	2	52.0	44.5	2.25	37.0	1.75	41.5	1.25	51.0	58.5
49	LP	2	54.0	47.0	2.50	39.0	2.25	41.0	2.00	52.5	51.0
50	LP	2	44.0	39.0	2.50	35.5	2.25	41.5	1.50	45.5	46.5
51	LP	2	51.0	46.0	3.00	41.5	2.25	45.0	1.75	48.5	52.0
52	LP	2	50.0	46.0	2.75	40.0	2.25	42.0	2.00	52.5	54.0
53	LP	3	59.0	53.5	2.25	45.0	1.75	55.0	1.00	52.0	54.5
54	LP	3	60.0	52.5	2.50	45.0	1.75	50.0	1.50	59.0	54.0
55	LP	3	56.0	49.5	2.50	M	2.25	55.0	1.75	51.0	55.0
56	LP	3	59.0	53.5	2.00	46.0	1.25	57.5	0.75	61.5	63.0
57	LP	3	56.0	51.0	3.00	46.0	2.50	53.0	2.00	54.0	52.5
58	LP	3	52.5	49.0	2.25	36.0	1.50	44.0	1.00	54.0	51.5
59	LP	3	52.0	46.5	2.75	43.5	2.00	48.0	1.75	48.0	48.0
60	LP	3	53.5	49.0	2.00	40.5	1.50	49.0	1.50	47.0	48.5
61	LP	3	52.0	44.0	2.00	M	M	46.5	1.50	M	0.0
62	LP	3	58.5	52.5	2.25	45.0	1.75	54.5	1.50	62.0	60.5
63	LP	3	58.0	54.5	2.75	44.5	1.50	50.0	1.50	56.0	63.5
64	LP	3	50.0	46.0	2.00	38.0	1.50	46.0	1.75	50.5	48.0
65	LP	3	64.0	57.5	3.00	52.5	1.75	57.0	1.50	60.0	58.0
66	LP	3	50.0	47.0	2.25	40.0	1.50	44.0	1.50	50.0	58.5
67	LP	3	56.0	50.0	1.75	43.0	1.75	50.0	1.50	56.0	57.5
68	LP	4	60.5	56.0	2.25	48.0	1.25	M	M	64.5	64.0
69	LP	4	53.0	51.0	2.75	46.0	2.25	52.5	1.75	58.5	56.0
70	LP	4	67.0	61.5	2.75	53.0	2.25	58.0	1.75	60.0	62.0
71	LP	4	58.0	52.0	2.50	48.5	1.75	57.0	1.75	52.0	50.0
72	LP	4	60.0	54.0	2.50	48.0	2.00	56.0	1.75	55.0	52.0
73	LP	4	64.0	56.0	2.50	44.0	2.25	47.0	2.00	58.5	61.0
74	LP	4	56.0	51.0	2.25	45.0	1.75	52.0	1.50	54.0	54.5
75	LP	4	61.0	53.0	2.50	47.5	2.00	55.0	1.50	57.0	61.0
76	LP	4	70.0	64.0	3.00	52.0	1.75	59.5	0.75	48.0	57.0
77	LP	4	55.0	49.0	2.25	43.0	2.00	50.0	1.75	54.0	59.5
78	LP	4	52.0	49.0	2.25	43.0	2.00	49.0	2.00	62.0	53.0
79	LP	4	59.0	55.0	2.75	47.5	2.00	54.5	2.25	60.0	61.0
80	LP	5	58.5	53.5	2.50	46.5	2.00	55.5	1.75	58.0	43.5
81	LP	5	61.5	52.0	2.50	45.5	1.50	56.5	1.05	53.0	54.0
82	LP	5	65.5	59.0	2.75	52.5	2.00	58.5	2.00	55.5	56.0
83	LP	5	51.0	49.0	2.00	40.5	1.25	46.0	0.75	48.0	49.0
84	LP	5	55.0	52.0	2.25	45.5	2.00	50.5	1.50	42.5	47.5
85	LP	5	64.0	59.0	2.25	52.5	1.75	63.5	1.50	65.0	63.5
86	LP	5	55.5	51.5	2.00	45.0	1.50	51.0	1.75	47.5	54.5
87	LP	5	52.5	53.0	2.00	42.0	1.50	52.0	1.50	57.0	55.0

Appendix table A 18 cont

Ewe no.	Treatment	Age (yrs)	Liveweight 16 Nov 81	Liveweight 21 Jan 82	Cond.score 21 Jan 82	Liveweight 1 Mar 82	Cond.score 1 Mar 82	Liveweight 8 April 82	Cond.score 8 April 82	Liveweight 20 May 82	Liveweight 13 Aug 82
88	HP	2	44.0	38.0	2.25	36.0	1.75	43.0	1.50	46.0	46.0
89	HP	2	49.0	43.0	2.50	42.5	2.25	44.0	1.75	50.0	53.5
90	HP	2	51.5	48.0	2.75	47.5	2.25	48.0	2.00	51.0	46.0
91	HP	2	50.5	46.0	2.50	44.5	2.00	47.0	2.00	52.0	54.0
92	HP	2	52.0	45.0	2.25	43.5	2.00	46.0	1.50	55.0	53.5
93	HP	2	45.0	38.5	2.50	38.5	2.25	41.5	1.75	47.0	44.0
94	HP	2	46.0	45.0	1.50	40.0	2.00	39.5	1.75	49.0	54.0
95	HP	2	48.0	43.5	2.50	40.5	2.00	45.0	1.50	46.5	45.0
96	HP	2	53.0	43.0	2.50	37.0	2.00	38.0	1.50	51.0	61.0
97	HP	2	54.0	47.0	3.00	48.0	2.50	46.0	2.00	53.0	61.5
98	HP	2	53.0	45.5	2.75	46.5	2.25	47.0	1.75	50.0	53.0
99	HP	2	56.5	52.0	3.00	48.5	2.25	46.5	1.50	53.5	50.0
100	HP	2	40.0	37.0	1.75	36.0	1.75	37.0	1.50	42.5	49.0
101	HP	3	51.0	47.0	2.50	47.5	2.25	50.5	1.75	55.0	57.0
102	HP	3	63.0	56.0	3.00	56.0	2.50	59.0	2.50	M	60.0
103	HP	3	59.5	54.5	2.50	55.0	1.75	56.0	1.50	61.0	56.0
104	HP	3	66.0	63.0	2.50	62.0	2.00	60.0	1.75	66.0	77.0
105	HP	3	56.5	52.0	2.50	50.5	2.00	52.0	1.50	57.0	56.0
106	HP	3	54.0	51.0	2.25	44.0	1.50	45.0	1.50	53.0	58.0
107	HP	3	61.0	55.0	2.25	50.0	2.50	49.0	2.25	62.0	67.0
108	HP	3	51.0	44.5	2.25	43.5	1.75	37.0	1.00	50.5	57.0
109	HP	3	57.0	52.0	2.25	49.0	1.75	50.5	1.50	57.5	57.0
110	HP	3	65.0	58.5	2.50	59.5	2.50	62.0	1.50	66.0	64.0
111	HP	3	54.0	47.0	2.25	44.5	1.75	47.5	1.25	51.5	47.5
112	HP	3	54.0	46.5	2.25	43.5	1.75	48.0	1.75	52.0	46.5
113	HP	3	56.0	48.5	2.75	50.5	2.50	52.0	2.50	49.5	60.0
114	HP	3	53.0	50.0	2.50	51.5	2.00	52.5	1.75	54.0	56.0
115	HP	4	55.0	49.0	2.25	50.0	2.00	50.0	1.50	54.5	56.5
116	HP	4	65.0	59.5	2.50	61.5	2.50	62.5	2.00	73.5	71.0
117	HP	4	63.5	55.5	2.50	58.5	2.50	61.0	2.00	58.0	61.0
118	HP	4	61.5	55.0	2.75	56.0	2.50	50.0	2.50	62.0	66.0
119	HP	4	64.0	60.0	3.25	61.5	2.75	64.5	2.50	65.0	62.0
120	HP	4	56.0	52.0	2.50	53.5	2.25	56.5	2.00	56.0	57.0
121	HP	4	66.0	59.5	2.75	64.0	2.75	68.0	2.50	65.5	65.0
122	HP	4	61.5	56.0	2.50	54.0	1.75	57.0	2.00	57.0	55.0
123	HP	4	55.5	52.0	2.50	53.5	2.00	55.5	1.75	55.0	55.0
124	HP	4	63.0	61.0	3.00	63.5	2.75	61.5	2.50	67.0	63.0
125	HP	4	58.0	51.0	2.50	50.5	2.25	52.5	1.75	62.5	62.0
126	HP	4	52.5	48.0	2.00	46.0	2.00	47.5	1.50	55.0	55.0
127	HP	4	70.0	60.5	2.50	64.5	2.25	66.0	1.75	63.0	61.0
128	HP	4	58.0	50.5	2.00	50.0	1.75	48.5	1.50	63.0	64.0
129	HP	5	71.0	59.5	2.00	60.0	2.00	61.5	1.75	72.0	64.0
130	HP	5	51.0	53.0	2.75	53.0	2.50	55.0	2.25	54.0	53.0
131	HP	5	53.0	49.0	2.00	47.0	2.25	49.0	1.75	55.0	55.5
132	HP	5	55.5	60.5	1.75	50.5	1.50	54.5	1.75	50.0	53.0
133	HP	5	57.5	49.5	2.25	50.0	2.25	53.5	1.50	49.0	43.5
134	HP	5	58.0	50.0	2.00	51.0	2.00	56.0	1.50	52.0	52.0
135	HP	5	64.0	58.0	2.75	55.0	2.25	57.5	1.75	56.0	54.0
136	HP	5	60.0	53.5	2.75	54.0	2.50	58.0	2.25	60.0	56.0

Appendix table A 18 cont

Ewe no.	Treatment	Age(yrs)	Liveweight 16 Nov 81	Liveweight 21 Jan 82	Cond.score 21 Jan 82	Liveweight 1 Mar 82	Cond.score 1 Mar 82	Liveweight 8 April 82	Cond.score 8 April 82	Liveweight 20 May 82	Liveweight 13 Aug 82
137	HE	2	42.5	36.5	2.75	35.0	2.50	40.0	1.75	41.5	40.5
138	HE	2	49.0	45.0	2.75	41.0	2.50	44.5	2.00	44.5	46.5
139	HE	2	48.5	42.5	2.75	41.0	2.25	43.0	2.00	52.5	49.0
140	HE	2	50.0	45.0	2.50	43.0	2.00	45.0	1.50	49.0	48.5
141	HE	2	47.0	42.0	2.75	40.0	2.00	43.0	2.00	45.0	44.0
142	HE	2	57.0	50.0	2.50	51.5	2.25	51.0	1.75	58.0	54.0
143	HE	2	50.5	44.0	2.50	42.5	2.25	45.0	2.00	49.0	53.0
144	HE	2	44.0	40.5	2.75	39.0	2.25	41.5	2.00	51.5	50.0
145	HE	2	46.0	41.0	2.75	38.0	2.25	38.0	1.75	46.0	42.5
146	HE	2	45.5	42.0	2.50	38.0	2.25	40.5	1.75	47.0	47.0
147	HE	2	48.0	42.0	2.50	41.5	2.50	41.5	2.25	51.0	53.0
148	HE	2	49.0	43.0	2.50	40.5	1.75	42.0	2.00	49.5	49.5
149	HE	2	41.5	35.0	2.50	35.0	2.25	38.0	1.50	51.0	44.0
150	HE	2	45.0	40.5	2.25	37.5	2.25	40.0	1.50	45.0	49.0
151	HE	3	57.0	50.0	1.75	43.0	1.50	45.0	1.25	59.5	66.0
152	HE	3	55.0	52.5	2.25	49.5	2.00	50.0	1.25	58.0	66.0
153	HE	3	50.5	42.5	2.25	39.5	1.75	51.0	1.50	49.0	50.5
154	HE	3	64.0	57.0	3.00	57.0	2.75	57.0	2.00	70.0	64.5
155	HE	3	50.0	40.0	2.25	40.0	1.50	42.0	1.00	49.0	47.5
156	HE	3	57.0	53.5	2.50	52.0	1.75	55.0	2.25	61.5	58.5
157	HE	3	54.0	45.0	2.25	46.0	1.50	49.0	1.50	59.0	57.5
158	HE	3	61.0	53.0	2.00	46.0	2.25	48.5	1.75	63.0	55.5
159	HE	3	61.0	54.0	2.25	57.5	2.50	58.0	2.00	64.0	61.5
160	HE	3	61.0	56.0	2.50	52.5	2.50	53.0	2.25	67.5	65.0
161	HE	3	67.0	58.5	2.50	54.0	2.25	53.0	2.50	70.0	67.0
162	HE	3	51.5	46.0	2.00	42.0	1.75	48.0	1.00	53.0	52.0
163	HE	3	57.0	49.0	2.50	46.0	2.00	39.0	1.50	53.0	55.0
164	HE	3	56.0	50.0	2.50	45.0	2.25	47.0	2.25	58.0	58.0
165	HE	3	47.0	41.0	2.00	40.5	1.50	41.0	1.25	49.5	50.5
166	HE	3	58.5	48.0	2.50	49.0	1.75	52.0	2.00	61.0	58.0
167	HE	4	54.0	52.5	2.25	51.5	2.25	53.5	2.00	66.0	58.0
168	HE	4	58.5	52.0	2.75	56.5	2.75	59.0	2.50	64.0	61.0
169	HE	4	60.5	52.0	2.00	54.5	1.75	55.5	1.50	67.0	69.5
170	HE	4	61.5	54.5	2.25	61.0	2.00	69.0	2.00	68.0	65.0
171	HE	4	61.0	54.0	2.00	55.5	2.25	56.0	2.25	62.5	59.0
172	HE	4	61.0	57.5	2.75	57.5	2.50	59.5	2.25	61.5	60.0
173	HE	4	60.0	53.5	3.00	56.5	2.00	58.0	2.25	62.0	62.0
174	HE	4	59.0	52.5	3.00	56.0	2.50	61.5	2.50	62.0	60.5
175	HE	4	61.0	59.0	2.75	60.5	2.50	63.0	2.25	70.5	68.0
176	HE	4	63.0	56.0	2.75	55.5	2.75	59.0	2.50	61.0	60.0
177	HE	4	63.5	52.0	2.75	52.5	2.50	54.0	1.50	67.0	65.0
178	HE	4	59.0	54.5	2.75	57.0	3.00	63.0	2.00	63.0	62.5
179	HE	4	59.0	52.0	2.50	54.5	2.25	58.0	1.75	59.0	61.5
180	HE	5	55.0	51.5	2.50	54.5	2.25	48.0	1.75	59.0	64.0
181	HE	5	71.0	63.0	2.50	57.5	2.25	64.0	1.75	66.0	61.0
182	HE	5	59.5	58.0	2.50	58.5	2.25	64.0	2.50	56.0	54.5
183	HE	5	51.0	47.5	2.50	50.0	2.25	54.0	2.00	50.0	47.5
184	HE	5	57.0	52.0	2.75	49.5	2.75	50.0	2.50	58.0	61.0
185	HE	5	58.0	56.5	1.50	52.0	2.25	58.0	1.75	57.0	52.0
186	HE	5	57.5	52.0	2.00	50.0	2.00	54.0	1.50	55.5	52.5

APPENDIX TABLE A19

The performance of lambs born to individual ewes in Experiment 5. Treatments LE,LP,HP and HE comprise ewe nos 1 to 37, 38 to 87, 88 to 136 and 137 to 186 respectively.

Treatment LE: ewe nos 1 to 37

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 82	Live weight(kg) 13 Aug 82
1	15 April	M	2.8	11.5	27.0
2	Barren				
3	4 May	M	2.3	8.5	27.0
4	27 April	M	4.3		
5	15 April	M	1.0		
6	25 April	F	2.3		
7	16 April	M	1.8		
8	24 April	F	3.2	9.0	23.0
9	20 April	M	2.9	10.0	22.0
10	27 April	F	3.2	11.0	31.0
11	24 April	F	2.5	7.0	22.0
		F	3.0	7.0	20.5
12	16 April	M	4.8	16.5	32.0
13	26 April	F	3.5	10.5	31.0
		M	4.5		
14	26 April	F	3.8	12.0	26.0
15	14 April	M	3.2	12.0	22.5
		M	3.1	12.0	22.5
16	Aborted				
17	23 April	F	3.1	9.5	22.0
		F	3.3	9.0	23.0
18	29 April	F	4.7	12.0	30.0
19	16 April	F	3.7	13.5	31.5
20	30 April	F	4.0	10.5	27.0
21	23 April	F	2.9	9.5	23.5
		M	2.9	10.0	18.5
22	Barren				
23	24 April	F	2.5	5.5	
		F	2.7	*	
24	25 May	F	4.1	*	
25	26 April	M	3.8	11.0	26.0
		F	2.0	7.0	22.5
26	14 April	M	3.1		
27	30 April	M	3.7	10.5	24.5
28	23 April	M	2.3	8.0	25.5
		M	3.3	11.0	25.0
29	23 April	M	4.2	*	30.0
30	24 April	M	3.6	11.0	24.5
		M	3.3	9.5	23.5
31	11 April	F	2.9	12.5	26.5
		F	2.8	11.5	26.0

Treatment LE cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 80	Live weight(kg) 13 Aug 82
32	13 April	M	2.6	10.0	
		F	3.0	11.0	25.5
33	22 April	F	3.4	11.0	25.0
		F	3.2	9.5	
34	14 April	F	4.1	16.0	27.5
35	27 April	F	4.3	9.0	26.5
36	Barren				
37	21 April	M	4.2	14.5	34.5
Treatment LP: ewe nos 38 to 87					
38	22 April	F	1.6		
39	11 April	M	2.2		
		F	2.1		
40	16 April	M	4.0	15.0	29.5
41	29 April	M	2.6	8.5	23.0
		F	2.0	*	
42	18 May	F	3.5	*	20.0
43	Barren				
44	Aborted				
45	24 April	M	3.2	9.5	23.0
46	10 April	F	2.8	13.0	29.0
47	18 April	M	2.4	10.0	24.5
		F	2.5	10.5	27.0
48	22 April	M	2.0		
49	24 April	M	3.6	13.0	30.0
50	15 April	F	3.4	12.0	26.5
51	1 May	F	3.5	10.5	27.0
		F	2.9	8.5	26.5
52	25 April	M	3.5	12.0	
53	22 April	M	2.9	7.5	17.5
		M	3.2	8.5	19.0
54	27 April	F	4.5	12.5	
55	Decomposing foetuses				
56	14 April	M	3.5		
		F	2.4	12.0	
57	30 April	F	3.2	8.5	22.0
		F	3.3	8.5	25.5
58	27 April	F	4.0	*	28.0
59	20 April	M	2.9	10.0	22.5
		F	3.1	10.0	23.5
60	16 April	F	2.1	8.5	19.0
		M	2.6	10.5	20.5
61	11 April	M	2.2		
		M	2.1		
62	27 April	M	4.1	11.5	26.0
63	17 April	M	2.1	*	
		M	2.2		
64	23 April	F	4.4	13.0	29.0
65	27 April	F	3.5	11.0	21.5
		M	4.3	11.0	25.0

Treatment LP cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 82	Live weight(kg) 13 Aug 82
66	30 April	F	2.9		
		M	2.5		
67	14 April	M	3.5	12.5	30.0
68	8 April	F	2.4	15.0	31.0
69	11 May	M	4.1	7.0	19.5
		M	4.1	*	24.0
70	24 April	F	2.9	9.5	23.0
		M	2.5	8.0	20.5
71	23 April	F	3.2	10.0	22.0
		F	2.9	8.5	17.0
72	18 April	M	2.6	12.5	27.0
		F	2.4	9.5	22.5
73	Barren				
74	23 April	M	2.0		
		M	3.3	12.5	29.5
75	15 April	M	2.6		
		M	2.8		
76	10 April	M	2.5	11.5	
		F	2.0		
77	26 April	F	3.2	11.0	
		F	2.4		
78	25 April	F	3.5	10.5	24.5
79	18 April	F	2.9	10.5	28.0
		M	2.7	7.0	18.5
80	26 April	M	5.4		
81	20 April	F	3.1	8.5	21.5
		F	2.9	7.5	20.0
82	21 April	F	4.0	11.0	26.0
		M	3.6	10.0	
83	28 April	F	2.0	*	
		M	2.5		
84	28 April	M	4.0	12.0	18.5
		F	2.8	8.5	14.0
85	14 April	M	4.1	18.0	35.0
86	27 April	M	3.5	*	
		M	3.0		
87	22 April	F	2.5	10.0	16.5

Treatment HP: ewe nos 88 to 136

88	15 April	M	2.2	10.0	27.0
89	19 April	F	2.6		
90	23 April	M	3.7	10.0	19.0
		F	3.5	10.5	24.5
91	23 April	F	4.2	13.0	30.5
92	17 April	F	3.2	13.0	24.0
93	24 April	M	4.0	12.5	29.5
94	Barren				
95	17 April	F	3.1	13.0	28.5

Treatment HP cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 82	Live weight(kg) 13 Aug 82
96	Barren				
97	30 April	M	5.2		
98	16 April	F	3.4	12.0	27.5
99	20 April	M	2.4	8.6	21.0
		M	2.2	9.5	20.5
100	20 April	M	3.1	*	
101	15 April	M	4.5	18.5	34.5
102	25 May	M	4.6	*	*
103	25 April	M	3.7	10.0	26.0
		M	3.5	9.5	22.5
104	9 April	F	1.5		
		M	*		
105	15 April	F	2.6	12.0	29.5
		F	3.1	14.0	33.0
106	29 April	M	5.4	12.5	28.5
107	Barren				
108	Aborted				
109	18 April	M	2.5	9.5	29.0
		F	2.5	9.0	
110	20 April	F	3.5	11.0	28.0
		M	3.6		
111	18 April	F	3.9	13.0	
112	28 April	F	3.1	10.0	18.5
		F	3.3	8.5	23.0
113	29 April	F	5.3	13.0	29.5
114	22 April	F	3.2	10.0	23.5
		F	3.0	10.0	21.5
115	27 April	F	4.5	10.0	28.0
116	26 April	M	2.5		
		F	3.2	10.5	28.0
117	25 April	M	3.9	10.0	
		M	3.9	9.5	24.5
118	Barren				
119	21 April	F	4.0	12.0	26.5
		F	4.0	11.0	23.0
120	26 April	F	3.5	9.5	21.0
		F	3.0	9.0	25.0
121	28 April	M	3.8	9.5	27.0
		M	3.8	12.0	27.5
122	26 April	M	3.2	9.5	26.0
		F	2.6	7.5	23.0
123	25 April	F	3.0	8.5	22.5
		F	3.4	9.5	24.0
124	24 April	F	4.0	12.0	30.5
125	23 April	M	5.5		
126	22 April	F	2.6	12.0	30.5
127	17 April	M	3.5	12.0	24.0
		F	3.0	10.0	22.0
128	3 May	F	4.0	9.5	27.0
129	23 April	M	4.2	13.0	29.0

Treatment HP cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 82	Live weight(kg) 13 Aug 82
130	24 April	F	3.0	8.0	33.0
		F	3.0	9.0	21.0
131	26 April	F	4.4	13.5	32.5
132	16 April	M	3.0	10.5	23.0
		M	3.0	11.0	16.5
133	18 April	M	4.0	15.5	28.5
134	26 April	F	3.5	10.0	22.0
		F	4.0	10.0	21.5
135	28 April	F	4.3	12.0	29.0
136	14 April	F	3.1	12.0	24.5
		M	3.0	13.0	26.0
Treatment HE: ewe nos 137 to 186					
137	21 April	M	2.8	8.0	14.5
		M	2.9	9.5	19.5
138	Barren				
139	Aborted				
140	13 April	M	3.2	12.0	24.5
		M	2.5	11.0	23.0
141	Aborted				
142	Aborted				
143	27 April	M	2.8	5.5	18.5
144	30 April	M	4.7	12.0	29.5
145	23 April	F	3.8	9.0	22.5
146	27 April	M	5.0	12.0	33.0
147	4 May	F	5.9	12.0	34.0
148	18 April	M	5.1	18.5	34.5
149	27 April	F	4.6	12.5	28.5
150	25 April	F	3.4	10.0	22.0
		M	3.9	12.0	25.5
151	26 April	M	4.8	*	28.0
152	16 April	F	2.6	12.5	28.5
		M	3.4		
153	19 April	F	3.0	12.5	32.5
		F	2.2		
154	15 April	M	4.8	18.0	32.5
155	29 April	F	3.3	10.5	28.0
156	15 April	F	3.4		
		M	3.6	16.5	31.5
157	27 April	M	2.5	9.0	26.0
		M	2.1	9.0	18.5
158	11 April	F	1.8		
159	17 April	F	3.5	9.5	27.0
160	10 April	F	3.0	13.0	28.0
161	11 May	F	4.9	8.0	30.5
162	15 April	F	2.9	11.5	28.0
163	13 April	M	3.9	16.5	
164	28 April	F	4.2	10.5	26.5
165	28 April	F	3.7	10.0	26.0

Treatment HE cont

Ewe No	Date of birth	Sex	Birth weight(kg)	Live weight(kg) 20 May 82	Live weight(kg) 13 Aug 82
166	22 April	F	3.1	8.5	22.5
167	22 April	F	4.1	12.5	30.0
168	29 April	F	4.7		
169	1 May	F	3.5	8.0	24.5
170	28 April	M	3.3	9.0	23.0
171	2 May	F	4.1	9.5	27.0
172	1 May	M	4.0	9.0	
173	Barren				
174	25 April	M	3.1		
175	29 April	F	3.9	9.0	25.5
176	26 April	M	4.2	14.5	
177	21 April	M	4.0	*	26.0
178	9 April	M	3.5	17.5	29.0
		M	1.8		
179	23 April	F	3.9	13.0	29.0
180	Barren				
181	22 April	M	4.6	15.0	34.0
182	23 April	F	3.8	10.5	27.0
		M	3.6	12.0	28.0
183	16 April	M	3.1	11.5	24.5
		M	2.7	11.0	25.0
184	Barren				
185	28 April	F	3.4	8.0	22.0
		F	3.4	9.5	20.0
186	27 April	F	3.1	7.0	21.0
		F	3.5	8.0	20.0

* The lamb was alive, but the relevant information was not recorded.

APPENDIX TABLE A 20

Concentrations of plasma urea, glucose and NEFA for each treatment for each sampling occasion in mid pregnancy in Experiment 5 (means of 20 observations).

	Treatment	Sampling occasion								
		25 Jan	1 Feb	8 Feb	15 Feb	22 Feb	1 March	9 March	VI	H
Urea concentration (mM)	LE	1.44	1.48	1.59	2.01	1.91	1.87	*	§1.303	1.247
	LP	1.20	1.65	1.23	1.55	1.51	1.71	*		
	HP	1.27	1.42	1.30	1.46	2.30	1.75	1.94		
	HE	2.08	2.81	1.98	2.38	3.48	2.46	1.21		
Glucose concentration (mM)	LE	3.12	3.20	3.34	3.27	3.08	3.28	*	§1.070	1.062
	LP	3.24	3.36	3.15	3.36	3.17	3.03	*		
	HP	3.23	3.22	3.42	3.06	3.36	2.93	3.12		
	HE	3.39	3.37	3.56	3.26	3.88	3.04	3.17		
NEFA concentration (mM)	LE	595	613	951	689	842	790	*	Ave	SE
	LP	792	616	1026	762	780	960	*	58.1	50.7
	HP	523	341	713	784	608	986	760		
	HE	596	613	519	917	582	736	911		

* Late pregnancy supplementation started.
VI is error for comparing different treatments and/or weeks
H is error for comparing weeks for the same treatment.
§ Two means differ if their ratio (>1) is greater than the tabulated value ($p<0.05$)

APPENDIX TABLE A 21

Concentrations of plasma urea, NEFA, 3-OHB and glucose in late pregnancy, Experiment 5 (means of 20 observations).

	Treatment	Sampling occasion					Error	
		9 March	15 March	22 March	29 March	5 April	VI	H
Urea concentration (mM)	LE	1.13	0.93	0.94	0.98	2.02		
	LP	0.98	0.79	0.52	0.72	1.07	*1.51	
	HP		2.10	0.81	0.86	2.21		1.36
	HE		1.14	1.14	1.56	3.02		
NEFA concentration	LE	821	471	677	1039	605	Ave	SED
	LP	1034	447	647	915	484	93.1	68.9
	HP		405	705	991	594		
	HE		377	689	922	590		
3-OHB concentration (mM)	LE	0.40	0.53	0.54	0.60	0.50		
	LP	0.46	0.60	0.59	0.75	0.52	*1.20	
	HP		0.51	0.65	0.52	0.51		1.17
	HE		0.44	0.67	0.70	0.54		
Glucose concentration (mM)	LE	3.16	2.86	2.97	2.97	3.17	Ave	SED
	LP	3.08	3.01	2.70	2.49	3.47	0.158	
	HP		2,83	2.93	3.33	2.95		0.137
	HE		3.31	3.15	3.25	3.54		

H is error for comparing weeks for the same treatment.
VI is error for comparing treatments and/or weeks.

* Two means differ if their ratio (>1) is greater than the tabulated value ($p<0.05$).

APPENDIX TABLE A 22

Supplement intakes in late pregnancy by ewes in Treatment LE, Experiment 5, in relation to some aspects of their performance and concentration of plasma 3-OHB, NEFA, urea and glucose.

Ewe no.	Supplement intake(g DM/ ewe/day)	Lamb birth-weight (kg)	Liveweight change(kg)	Cond.score 8 April 82	Plasma 3-OHB conc. (mM)	Plasma urea conc. (mM)	Plasma NEFA conc. (mM)	Plasma glu-cose conc. (mM)
1	40	2.8	4.5	1.75	0.61	1.91	1120	3.74
2	225	0.0	-4.0	1.75	0.50	0.38	663	2.84
3	363	2.3	4.5	2.25	0.43	2.20	792	3.62
4	138	4.3	4.0	2.25	0.81	0.51	1293	3.03
5	161	1.0	5.5	1.50	0.29	0.53	630	3.58
6	84	1.8	5.5	1.25	0.75	0.67	599	2.63
7	218	3.2	5.5	1.75	0.39	0.67	462	3.39
8	138	2.9	4.0	1.75	0.81	0.75	952	3.44
9	443	3.2	6.5	1.75	0.44	0.76	483	3.51
10	238	5.5	5.0	2.00	0.52	1.65	470	2.82
11	259	4.8	9.5	1.50	0.48	0.88	522	2.73
12	420	8.0	5.0	1.50	0.45	1.44	642	3.24
13	201	3.8	6.0	1.75	0.20	0.92	397	3.62
14	1222	6.3	7.5	1.50	0.33	1.23	630	3.29
15	245	0.0	-2.0	1.50	0.34	0.53	565	3.49
16	389	6.4	2.5	1.50	0.54	0.26	720	3.49
17	205	4.7	3.5	1.25	0.37	0.20	882	3.19
18	218	3.7	6.5	2.25	0.31	0.79	445	2.99
19	718	4.0	5.0	1.25	0.34	0.41	766	1.08
20	870	5.8	3.5	1.75	0.41	1.62	294	3.61
21	604	0.0	-0.5	2.00	0.38	0.99	432	3.43
22	507	5.2	2.5	1.50	0.60	1.40	612	3.14
23	416	4.1	1.5	1.50	0.42	0.21	509	2.80
24	269	5.8	0.5	2.00	0.29	0.43	462	3.07
25	477	3.1	4.0	2.25	0.46	0.35	599	3.37
26	349	3.7	7.0	1.75	0.50	0.60	496	2.68
27	356	5.6	5.5	1.00	0.52	1.18	384	3.08
28	655	4.2	6.0	1.75	0.45	1.24	475	3.30
29	802	6.9	7.5	2.25	0.43	1.58	423	3.32
30	631	5.7	5.5	1.75	0.48	1.24	882	3.44
31	487	5.6	8.0	1.75	0.80	0.03	535	2.48
32	497	6.6	5.0	1.50	0.49	0.89	432	3.23
33	154	4.1	5.0	1.50	0.47	0.62	630	4.41
34	339	4.3	3.5	1.50	0.44	1.40	676	3.33
35	87	0.0	-1.0	1.50	0.42	1.69	1036	3.01
36	1001	4.2	6.5	1.50	0.44	1.97	384	3.45
37	483	2.3	6.5	1.75	0.39	0.49	578	5.08

APPENDIX TABLE A 23

Intakes of supplement (g DM/ewe/day) by ewes for each measurement period of Experiment 7.

	Period					
	1	2	3	4	5	6
Ewe No.						
126	108	80	96	114	272	79
143	27	59	56	94	108	66
148	32	67	107	204	303	128
9105	269	241	218	368	411	252
9113	133	166	18	93	120	139
9119	114	133	126	173	195	179
9126	375	618	294	258	324	293
9157	218	339	154	196	206	141
8104	95	36	120	167	146	158
8128	335	351	142	291	172	81
8136	577	303	525	471	873	554
7107	80	248	205	153	209	176
7152	170	224	213	228	273	231

APPENDIX TABLE A 24

The number of meals of feedblock and the average duration of meals for each sheep during each measurement period in Experiment 7.

Sheep No.	126	143	148	9105	9113	9119	9126	9157	8104	8128	9136	7107	7152
Period 1													
No. meals	22	13	13	23	23	17	17	31	18	18	20	16	11
Ave meal length(min)	1.8	2.6	2.1	2.1	3.5	2.7	4.0	2.0	1.5	7.3	2.8	3.0	5.1
± SE	0.40	0.80	0.45	0.44	0.38	0.56	0.78	0.35	0.41	1.70	0.61	0.68	1.16
Period 2													
No. meals	25	23	10	30	27	17	31	32	20	28	19	34	24
Ave meal length(min)	1.7	2.0	3.5	3.3	4.3	2.4	3.7	3.2	2.3	9.1	4.1	6.4	5.1
± SE	0.40	0.32	1.01	0.70	1.01	0.74	0.75	0.41	0.47	1.97	1.21	1.02	1.24
Period 3													
No. meals	19	29	29	23	9	19	27	21	45	24	21	15	19
Ave meal length(min)	2.3	1.9	3.5	3.2	2.9	3.3	3.3	2.2	1.7	4.9	4.5	6.9	4.5
± SE	0.19	0.36	0.63	0.55	0.78	0.64	0.45	0.48	0.25	1.04	0.90	1.07	1.06
Period 4													
No. meals	18	16	23	12	24	18	13	12	15	12	14	10	21
Ave meal length(min)	1.9	5.4	2.5	3.8	2.2	4.0	2.8	4.0	2.7	5.3	4.4	5.6	5.5
± SE	0.46	1.31	0.52	0.89	0.32	0.52	0.49	0.97	0.82	1.25	0.63	1.32	0.92
Period 5													
No. meals	18	12	19	17	21	9	13	11	13	11	13	15	15
Ave meal length(min)	2.0	4.4	4.4	4.5	3.8	5.4	5.4	2.6	4.5	8.3	8.2	6.1	9.7
± SE	0.39	1.12	1.02	0.88	0.73	1.06	1.17	0.49	1.62	2.64	1.25	1.17	1.35
Period 6													
No. meals	9	17	15	11	16	10	18	13	12	9	14	13	9
Ave meal length(min)	1.0	4.2	4.4	3.2	3.6	4.3	3.9	2.0	1.6	7.9	4.8	4.1	7.4
± SE	0.31	0.79	0.56	0.56	0.78	0.85	0.63	0.31	0.26	1.83	0.76	0.68	1.61

Daylight hours observed were 46.0, 44.5, 34.5, 45.7, 35.4 and 44.8 hours in periods 1, 2, 3, 4, 5 and 6 respectively.

APPENDIX TABLE A 25

Results of interactions between pairs of sheep in Experiment 7: no. of wins where row individuals are dominant to column individuals; = indicates a non aggressive encounter; * no interaction observed.

Sheep nos.	126	143	148	9105	9113	9119	9126	9157	8104	8128	8136	7107	7152
126		1	2		=	1							
143			2	=	*								
148	1	2						=					
9105	1	2=	1		3	1	=	1	1				
9113	=	*	1				1	=	=		*		
9119	3	2	2	1	1		1						4
9126	1	4	1	5=	3	4		6	=		1	2	
9157	3	3	4=	1	7=	5	6		=				
8104	2	2	2	2	4=	1	=	2=			2=		
8128	9	5	1	12	8	6	3	8	3		10	10 =3	12=
8136	2	3	2	9	*	5	9	2	2=	1		3	6
7107	6	6	2	10	9	4	7	5	8	1 =3	2		11
7152	2	7	3	9	5	2	4	2	4	4=	6		

(= indicates a single non aggressive encounter, except where symbol preceeds a digit.)

APPENDIX TABLE A 26

Allocation of OF animals A, B, C and D to plots in Experiment 8.

Sampling occasion	Plot TL	TH	BL	BH
1	A B	C D	C D	A B
2	B C	A D	A D	B C
3	A C	B D	A D	B C
4	B D	A C	B C	A D
5	C D	A B	A B	C D

APPENDIX TABLE A 27

Weather records for January to April 1980, 1981 and 1982, as taken by the Meteorological Office. Temperatures, rainfall and snow cover measured at Whitehillocks (NGR 37/448799), 258 m above sea level, wind speed at Aberdeen (Dyce) Airport.

	Temperature				Rainfall	Snow*		Wind speed(knots)	
	Mean daily Max °C	Mean daily Min °C	No. days temp fell below 0°C		Total (mm)	No. days lying	Mean depth(cm)	Daily mean	Max daily mean
			Air	Grass					
1980									
January	3.0	- 1.3	23	26	125.8	22	2.9	8.1	23
February	5.5	- 0.2	16	18	137.2	11	8.6	7.6	23
March	5.1	- 0.8	16	24	145.3	12	8.1	8.5	22
April	11.6	2.2	5	19	7.3	0	0	9.4	34
1981									
January	6.6	- 1.6	22	27	74.8	18	5.6	9.8	26
February	4.9	- 0.8	20	22	66.5	10	5.6	10.5	32
March	8.2	0.8	14	17	120.8	10	8.2	9.8	27
April	11.1	0.2	17	21	25.2	3	6.0	8.4	21
1982									
January	4.1	- 2.8	17	22	90.2	21	43.5	7.4	29
February	5.9	0.0	10	17	116.5	0	0	11.1	33
March	7.6	0.5	12	23	125.2	5	8.0	10.4	34
April	11.5	1.9	7	18	35.1	1	1.0	8.9	28

* Snow cover was recorded when there was snow lying on the ground at 0900 GMT, covering at least 0.5 of the ground around the observation point. Snow depth is the measured amount of level undrifted snow at the observation site.

APPENDIX TABLE A 28

Variability of Cr concentration within and between feedblocks, measured in Experiment 2.

Within-feedblock variability

Two mid pregnancy and two late pregnancy feedblocks were sampled by drilling holes with a bit 1.5 cm in diameter through the block, or by scraping samples from the surface. The sample size was 10 g DM, and analyses were carried out as in Section 3.1.2.

	No. of samples per feedblock	Mean Cr conc. (mg/kg DM)	Coefficient of variation (%)
Mid pregnancy Feedblock A	12	4651	7
Mid pregnancy Feedblock B	11	2802	8
Late pregnancy Feedblock C	12	2103	2
Late pregnancy Feedblock D	12	1780	10

Between-feedblock variability

A single drilled sample was taken from 8 late pregnancy and 12 mid pregnancy feedblocks. The mean concentration of Cr and coefficient of variation for the late pregnancy feedblock were 1860 mg/kg and 5% respectively, and for the mid pregnancy feedblock, 3713 mg/kg and 15% respectively.